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THE DISTRIBUTION AND ABUNDANCE OF CHUM SALMON (Oncorhynchus Keta) IN THE UPPER YUKON RIVER BASIN AS DETERMINED BY A RADIO-TAGGING AND SPAGHETTI TAGGING PROGRAM: 1982 - 1983.

P.A.Milligan, W.O.Rublee, D.D.Cornett and
R.A.C.Johnston.

YUKON RIVER BASIN STUDY

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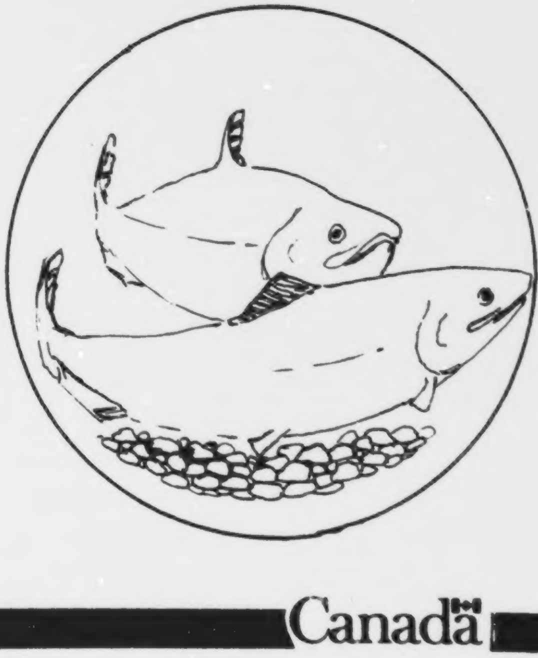
Fisheries and Oceans
Pêches et Océans

Whitehorse, Yukon 1984



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YUKON RIVER BASIN STUDY
TECHNICAL REPORT:
FISHERIES NO. 5b

THE DISTRIBUTION AND ABUNDANCE OF CHUM SALMON (Oncorhynchus keta) IN THE UPPER YUKON RIVER BASIN AS DETERMINED BY A RADIO-TAGGING AND SPAGHETTI TAGGING PROGRAM : 1982 - 1983

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January 1984
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WHITEHORSE, YUKON

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THE DISTRIBUTION AND ABUNDANCE OF CHUM SALMON (*Oncorhynchus keta*) IN THE UPPER YUKON RIVER BASIN AS DETERMINED BY A RADIO-TAGGING AND SPAGHETTI TAGGING PROGRAM : 1982-1983.

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Department of Fisheries and Oceans
Whitehorse, Yukon
1984

SUMMARY

A two year study of the distribution and abundance of adult chum salmon within Canadian portions of the Yukon River Basin was conducted in 1982-1983. This study was initiated as part of Fisheries and Oceans' contribution to the Yukon River Basin Study.

Chum salmon were live-captured by fishwheels and gillnets positioned on the Yukon River above the Canada/United States border. Spaghetti-tags were applied to 1,082 chum in 1982 and 3,176 chum in 1983 as part of a mark-recapture program. Radio transmitters were implanted into 114 chum in 1982. Radio-tagged chum were tracked into three of the five sub-basins located within the study area. These include the White, mainstem Yukon and Teslin sub-basins. Chum production in the Stewart and Pelly sub-basins appears to be minimal, although further research is needed to substantiate this.

Population estimates of 47,049 and 118,365 chum were determined for 1982 and 1983, respectively. The 1983 estimate was the largest recorded for the upper Yukon River Basin. The overall chum exploitation rates for the commercial, native subsistence and domestic fisheries in the study area were 26.2% in 1982 and 23.7% in 1983. The 1983 commercial chum catch of 24,812 in the area below the Stewart River was significantly higher than in previous harvests. This was the result of increased run magnitude and the availability of processing and marketing facilities.

Biological information was collected from the tagged sample, commercial fisheries and on the spawning grounds. Chum return to spawn at three to six years of age, although four and five year old chum are the predominant age classes.

The magnitude of the 1983 chum return suggests that upper Yukon chum stocks follow a four year cycle pattern similar to the one observed in the Fishing Branch River in the northern Yukon. Peak cycle year returns in this system occurred in 1971 and 1975.

The results of this study indicate that chum spawning sites in the upper Yukon River Basin are frequently associated with upwelling groundwater areas found in side channels. Chum spawning occurred in a large number of discrete side channels and sloughs within three principle spawning areas. Available information suggests that Canadian spawning areas produce approximately 50% of the total Yukon River drainage production. Additional yet undocumented spawning areas could exist, which would mean that the magnitude of chum spawning in the upper Yukon River Basin is greater than this report indicates. There is no evidence that this resource is declining.

The major recommendation of this report is that the Department of Fisheries and Oceans initiate some form of joint management and research with the Alaska Department of Fish and Game. This is necessary because Canadian bound chum stocks are intercepted in Alaskan fisheries on the lower Yukon River during their upstream migration.

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10 Fall chum catch and escapement - Yukon River

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1.0 INTRODUCTION

In 1982, the Department of Fisheries and Oceans commenced a two-year study of adult chum salmon (Oncorhynchus keta) Walbaum) in the Yukon River Basin. This project was undertaken as part of Fisheries and Oceans contribution to the Yukon River Basin Study (a joint study by Canada, Yukon, and British Columbia of the water and related resources of the Yukon River Basin).

The general objectives of the study were twofold:

1. to quantify the number of chum salmon returning to the Canadian portion of the Yukon River (excluding the Porcupine watershed);
2. to examine the distribution, relative abundance and migratory behaviour of specific spawning stocks.

To fulfill these objectives, two types of tagging studies were implemented: spaghetti tagging and recovery programs, carried out in 1982 and 1983; and a radio-tagging program, carried out in 1982 to complement the information collected in the tagging program.

Specifically, the objectives of the 1982 and 1983 chum spaghetti tagging and recovery programs were as follows:

1. to determine population estimates;
2. to determine exploitation rates and harvests in commercial, domestic and native subsistence fisheries;
3. to estimate spawning escapements;
4. to determine migration timing and rates;
5. to collect data on biological parameters such as age, size and sex composition.

The specific objectives of the radio-tagging program were as follows:

1. to determine the distribution of chum salmon within the Yukon River Basin;
2. to determine migratory rates and timing, behaviour, and spawning locations of individual chum salmon stocks;
3. to work out some of the logistic problems that could be encountered in a future radio-tagging program involving chum salmon.

Funding for the 1982 programs was provided by:

- the Yukon River Basin Study;
- the Department of Fisheries and Oceans and the Unemployment Insurance Commission through an Employment Bridging Assistance Program;
- Federal Summer Canada and Career Oriented Student Employment programs.

Funding for the 1983 program was provided by:

- the Yukon River Basin Study;
- the Federal and Yukon Territorial Governments through a Community Recovery Program;
- Employment and Immigration Canada through a New Employment Expansion and Development Program;
- Department of Fisheries and Oceans;
- the Federal Summer Canada Student Internship Progam.

1.1 Description of Watershed

The Yukon River Basin is the fifth largest in North America in terms of land area (844,800 km^2) and mean discharge (Todd 1970). Approximately 342,875 km^2 (40.6%) of the drainage area is located in Canada. The Yukon River originates on the British Columbia side of the north coastal mountains within 30 km of the Pacific Ocean and flows northward and westward for 3,018 km draining the southern portion of Yukon Territory and crossing the international boundary to continue through Alaska to the Bering Sea.

The Yukon River drainage in Canada consists of six major sub-basins (Alaska Department of Fish and Game 1982; Oswald and Senyk 1977; Canada 1979). These sub-basins, and their drainage areas, are as follows:

Major Sub-Basin	Drainage Area (km^2)
Pelly	50,200
Stewart	51,000
Teslin	35,500
White	38,100
Yukon mainstem	87,800
Porcupine	57,922

The Porcupine River, located in the northern Yukon Territory, was not included in the terms of reference of the study, because it drains into the Yukon River downstream of the Yukon-Alaska border, and is not considered part of the Yukon River Basin in Canada. The Yukon River Basin study area therefore consists of 238,300 km^2 in Yukon Territory and 24,300 km^2 in British Columbia (Figure 1).

In terms of drainage area, important tributaries of the Yukon River include the White, Donjek, Nordenskiold, Takhini, Teslin, Nisling, Pelly, MacMillan, Stewart, and Klondike Rivers. Major headwater lakes are the Kluane, Bennett, Marsh, Tagish, Atlin, Laberge, Teslin, and Mayo Lakes.

The Yukon River Basin in Canada transects sixteen distinct ecoregions described by Oswald and Senyk (1977). These ecoregions are not reviewed in detail in this report; however, it is useful to note general vegetation, temperature, and precipitation information. Vegetation consists primarily of boreal forest and alpine tundra, underlain by a zone of discontinuous permafrost. Mean annual temperatures in all regions are less than 0°C with extremes generally occurring in north-central

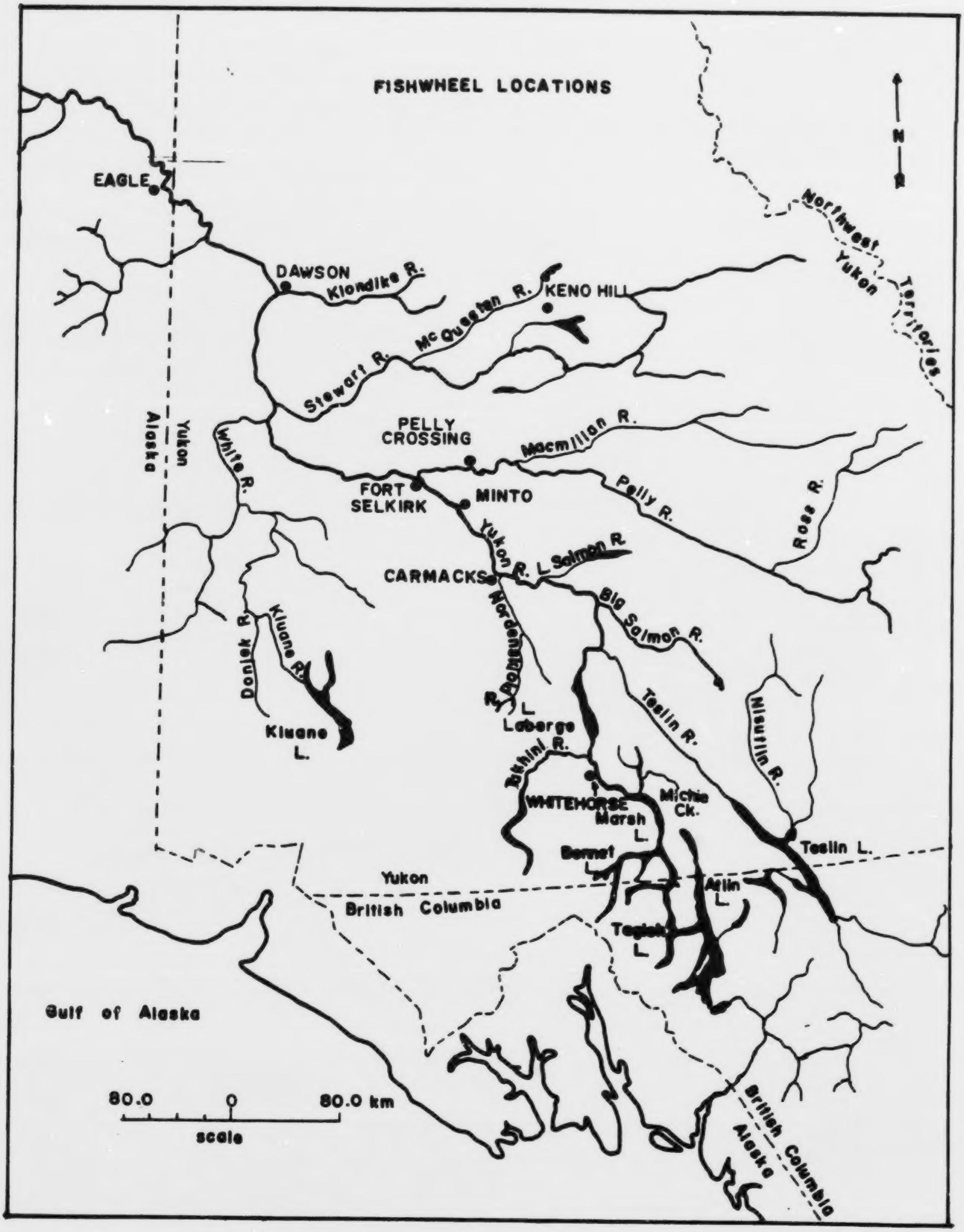
FISHWHEEL LOCATIONS
N
EAGLE
DAWSON
Klondike R.
KENO HILL
McQuesten R.
Stewart R.
PELLY CROSSING
Macmillan R.
FORT SELKIRK
MINTO
Pelly R.
Ross R.
White R.
Yukon R.
CARMACKS
L. Salmon R.
Big Salmon R.
Nordenskiold R.
L. Laberge
Donjek R.
Kluane R.
Kluane L.
Teslin R.
Nisutlin R.
Takhini R.
WHITEHORSE
Michie Ck.
Marsh L.
Bennet L.
Teslin L.
Atlin L.
Tagish L.
Yukon
Alaska
Yukon
British Columbia
Northwest Territories
Yukon
British Columbia
Alaska
Gulf of Alaska
80.0
0
80.0 km
scale

Figure 1 The upper Yukon River drainage

portions of the basin. Annual precipitation is generally low ranging from less than 375 mm in ~~the~~ southwest Yukon to over 750 mm in the east-central portions of the basin.

1.2 Chum Salmon Resource

Two runs of chum salmon, a "summer" run and a "fall" run, return annually to the Yukon River. The runs are distinguishable on the basis of morphological characteristics, migration timing and spawning destinations. Summer run chum enter the mouth of the Yukon River in early June and spawn in Alaska in the Tanana and Koyukuk Rivers and in the lower reaches of the Yukon River (Barton, 1982). There is no confirmation of summer chum spawning within Canadian portions of the Yukon River Basin. Fall run chum, which are larger fish with a higher oil content, commence their upstream migration in the Yukon River in mid-July and migrate to upper watershed spawning areas (Alaska Department of Fish and Game 1982; Barton, 1982). Migration through the Dawson area (Yukon Territory) occurs from August through early October and spawning occurs farther upstream from mid-September to early November. The chum return to the Yukon Territory represents the longest freshwater chum migration in North America.

Previous studies identified fall chum spawning areas in 32 Alaskan streams (Regnart and Geiger, 1982) and in nine Canadian streams (DFO spawning files; Walker, 1976). Major Alaskan spawning areas include the Sheenjek and Tanana Rivers (Figure 2), while major Canadian spawning areas include the Kluane River and the mainstem Yukon River. A number of Canadian spawning sites occur in side channels and sloughs in the Minto area, which are characterized by the frequent presence of upwelling groundwater (Walker, 1976). The Fishing Branch River in the Porcupine sub-basin is another important Canadian producer of fall chum (Appendix 1).

Cyclical returns to the Fishing Branch River were demonstrated during an enumeration program conducted from 1971 to 1975 (Elson, 1973, 1976). During peak years, escapements to this system totalled 250,000 - 300,000 (1971) and 353,282

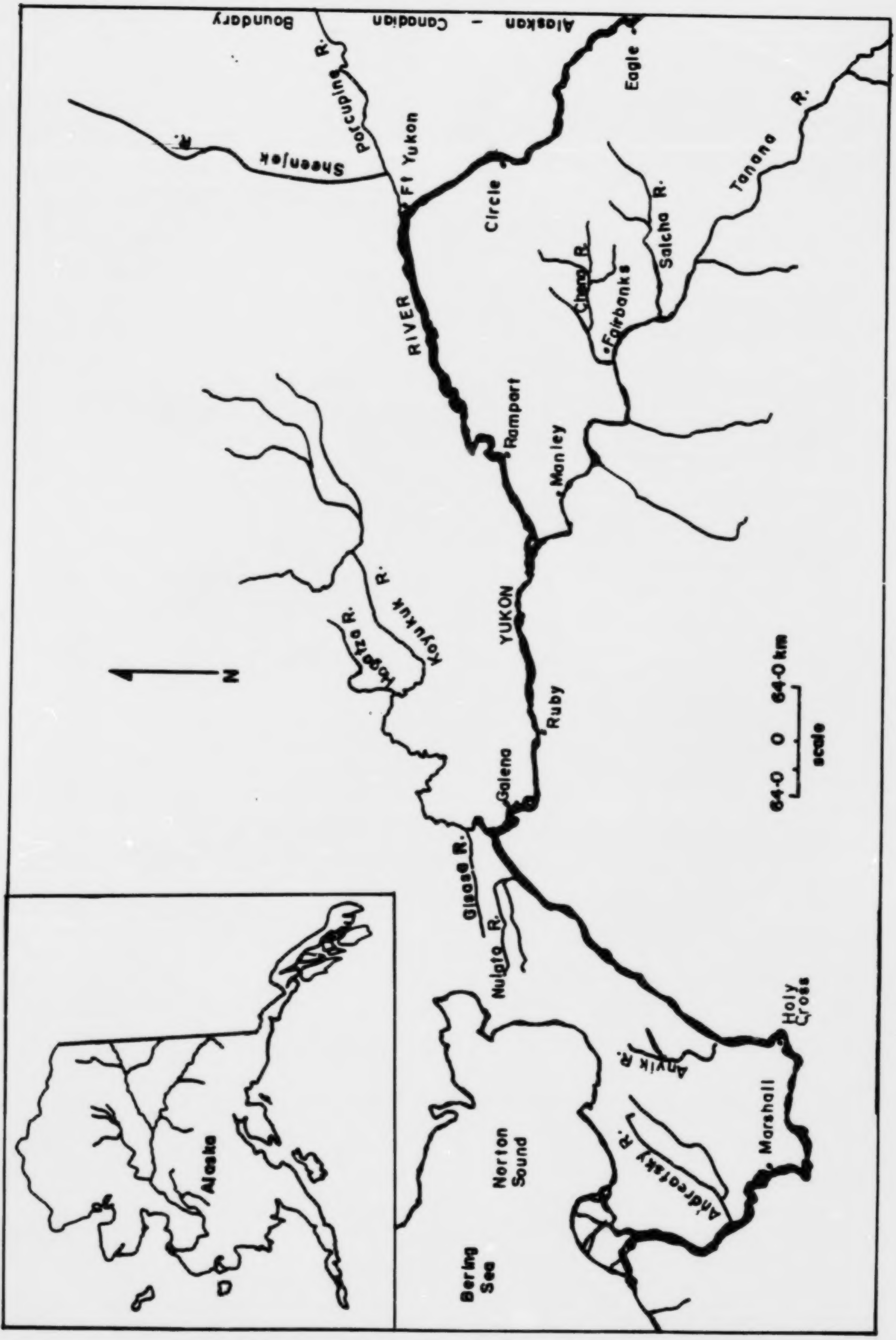
Alaskan - Canadian Boundary
Porcupine R.
Sheenjek R.
Ft Yukon
Eagle
Circle
Tanana R.
Salcha R.
Chena R.
Fairbanks
RIVER
Rampart
Manley
YUKON
Koyukuk R.
Hogatza R.
N
Ruby
Galena
64-0 0 64-0 km
scale
Gisasa R.
Nulato R.
Holy Cross
Anvik R.
Marshall
Norton Sound
Andreafsky R.
Bering Sea
Alaska

Figure 2 Yukon River drainage in Alaska

(1975) chum. If a similar four-year cycle exists in the study area, a peak chum return would appear in 1983.

To determine population estimates for chum salmon ascending the Yukon River in the Dawson City area, tag and recovery programs were conducted in 1973 (Sweitzer, 1974), 1974 (Brock, 1976) and 1978 (Johnston, in prep). The population estimates determined from these programs which were carried out in non-peak return years, ranged from 12,900 to 39,700 chum (Table 1). Additional fall chum population estimates for Alaskan and Canadian stocks combined are summarized in Table 2. From the information available, it would appear that the average annual return of Yukon River fall chum was in the order of magnitude of 627,000 fish in the 1975-1979 period (Table 2), although run magnitude approached an upper limit of approximately 900,000 chum during peak cycle year returns (1975 and 1979).

1.3 Resource Utilization

The main fisheries for chum salmon produced in the Yukon River Basin are the Alaskan and Canadian commercial, subsistence and domestic fisheries. Catch information for these fisheries is outlined below. In general, commercial exploitation of fall chum stocks in both Alaska and the Yukon Territory has increased, whereas domestic and subsistence catches have remained relatively stable. The overall exploitation rate of fall chum stocks averaged 63% for the 1975-1979 period (the most recent five-year period where population estimates are available). This exploitation rate was derived from the population and total catch estimates included in Table 2.

1.3.1 Alaskan Fisheries

Since the Yukon River is a transboundary river, fall chum destined for Canadian spawning areas must first migrate through Alaskan waters. An undetermined portion of Canadian bound chum stocks is intercepted in Alaskan fisheries. The commercial fall chum fishery in Alaska, begun in the early 1960's, recently expanded from an average catch of 38,800 over the 1964-68 period to an

TABLE 1. Previous Canadian estimates of Upper Yukon River fall chum salmon as determined from fishwheel tagging programs.

YEAR	LOCATION OF TAGGING SITE (KM. FROM RIVER MOUTH)	POPULATION ESTIMATE	CANADIAN CATCH * C - COMMERCIAL D - DOMESTIC S - SUBSISTENCE F - FISHERIES TEST NET	SOURCE
1973 a	2062	39,700	C - 2,806 S - 1,129* F - 667	(Sweitzer, 1974) DFO Files
1974 b	2062	15,800** 31,400	C - 4,646 S - 8,636* D - 466	(Brock, 1975) DFO Files
1978 a	2,030	12,900	C - 3,356 S - 5,482* D - 728 F - 611	(Johnston, in prep)

a Petersen disc tags only
b Combination of Petersen disc and spaghetti tags
* Excludes the Porcupine system
** The lower estimate was determined from Petersen disc tags only. The higher estimate was determined from spaghetti tags only, excluding catch and recovery data from the Dawson area.

TABLE 2. Previous Alaskan estimates of total Yukon River fall chum and total Canadian and Alaskan catches.

YEAR	LOCATION OF TAGGING SITE (km from river mouth)	POPULATION ESTIMATE	FALL CHUM CATCHES				SOURCE
			TOTAL CANADIAN	ALASKAN COMMERCIAL	ALASKAN SUBSISTENCE	TOTAL (CANADIAN & ALASKAN	
1961	1,221	131,000	16,176	42,577			(Regnart & Geigor, 1982)(ADF&G, 1982)
1962	1,221	114,000	19,800	53,160			SAME "
1974	-	514,000***	13,748	275,238			SAME "
1975	-	891,000***	20,600	265,156	109,536	395,292	SAME "
1976	-	349,000***	5,200	163,282	90,867	259,349	SAME "
1977	864 962	513,000***	12,479	248,737	88,331	349,549	SAME "
1978	962 1160	460,000***	9,566	243,737	99,867	353,170	SAME "
1979	-	922,388***	22,084	362,480	244,347	628,911	SAME "

*** Determined from Alaskan commercial and subsistence harvests and observed spawning escapements.

recently expanded from an average catch of 38,800 over the 1964-68 period to an average catch of 323,100 from 1978 to 1982. Historical data for the subsistence fishery in Alaska are lacking, however, recent subsistence catches averaged 167,500 chum (1978-82) (Alaska Department of Fish and Game 1982). It is generally believed that subsistence catches in Alaska have decreased because of greater participation in commercial fisheries and decreased requirements of chum for dog food.

In addition to the in-river commercial and subsistence fisheries, Alaskan offshore tagging studies indicate that an undetermined portion of Yukon River chum is also harvested in a U.S. domestic fishery in the South Unimak - Shumagin Islands area in the month of June. Catches in 1980 and 1981 averaged 551,500 chum, while catches between 1970 and 1979 averaged 277,000 chum (Alaska Department of Fish and Game, 1982).

1.3.2 Canadian Fisheries

In the Yukon Territory, a commercial fishery has operated in the vicinity of Dawson City since 1903. Although most of the effort still centres around Dawson, fishing sites are widely distributed along the Yukon River between Tatchun Creek and the Yukon-Alaska border. Prior to 1981, the lack of a processing plant and an organized marketing system contributed to relatively low chum salmon catch levels. For example, the 1964 to 1968 average catch was 2,400 chum. Substantial catch increases were recently recorded, primarily as a result of the operation of the Han Fisheries plant constructed in Dawson City in 1981. The significance of this new processing and marketing facility was evident in escalating catches over the 1978-1982 period, for which the average catch was 9,600 chum, and in the record commercial catch of 25,990 chum in 1983 (Table 3).

In addition to the Canadian commercial fishery, chum salmon are also harvested in subsistence and domestic fisheries in the Yukon Territory. Approximately 135 native food fish permits for salmon were issued in 1983. The communities that most actively participate in the native subsistence chum fishery include the following:

TABLE 3. Summary of Canadian and Alaskan gillnet catches of Yukon River fall chum salmon: 1964 - 1983.[a]

YEAR	CANADIAN CATCH				ALASKAN CATCH			TOTAL
	COMMERCIAL	DOMESTIC	SUBSISTENCE	TOTAL	COMMERCIAL	SUBSISTENCE	TOTAL	COMBINED CATCH
1964	1,929		4,181[b]	6,110	8,347	187,614	195,961	208,181
1965	2,071		9,800	11,871	23,317	126,848	150,165	173,907
1966	3,157		8,600	11,757	71,045	66,014	137,059	160,573
1967	3,343		13,600	16,943	38,274	83,664	121,938	155,824
1968	425		11,100	11,535	52,925	49,999	102,924	125,984
1969	2,279		5,500	7,779	131,291	56,755	188,046	203,604
1970	2,479		1,200	3,679	209,356	95,109	304,465	311,823
1971	1,761		14,000	15,761	189,594	125,182	314,776	346,298
1972	2,532		8,000	10,532	152,176	67,979	220,155	241,219
1973	2,806		6,938	9,744	232,090	78,257	310,347	329,835
1974	4,646	466	8,636	13,748	275,238	121,528	396,766	410,514
1975	2,500	4,600	13,500	20,600	265,156	109,536	374,692	395,292
1976	1,000	1,000	3,200	5,200	163,282	90,867	254,149	259,349
1977	3,990	1,499	6,990	12,479	248,739	88,331	337,070	349,549
1978	3,356	728	5,482	9,566	243,737	99,867	343,604	353,170
1979	9,084	2,000	11,000	22,084	362,480	244,347	606,827	628,911
1980	9,000	4,000	3,000	16,000	298,123	169,157	467,280	483,280
1981	15,260	1,611	5,110	21,981	486,059	188,343	674,402	696,383
1982	11,312	683	3,696	15,691	225,035	136,073	361,108	376,799
1983	25,990	300	800	27,090	303,882[c]	152,956[c]	456,838	483,928

[a] Catch figures from DFO files and from Alaska Department of Fish and Game (1982)

[b] Prior to 1973, Canadian records did not distinquish domestic from subsistence catches.

[c] Preliminary figure.

Community	General Fishing Area
Carmacks	- various locations in the Yukon River between the Little Salmon River and Tatchun Creek
Burwash Landing	- upper Kluane
Pelly Crossing	- mainly along the Yukon in the Minto and Fort Selkirk areas
Dawson City	- mainly in the Yukon River, close to the townsite

Domestic fishing licences are issued to non-native people who maintain a rural or homesteading lifestyle. Approximately 20 individuals currently participate in this fishery. During the past decade, catches have declined slightly in the subsistence and domestic fisheries. For the period 1973-1977, the average subsistence and domestic chum catches were 6,700 and 1,900, respectively; for 1978 to 1982, the averages were 5,700 and 1,800, respectively (Table 3).

1.4 Management

The management of all transboundary salmon stocks, which are stocks that originate in one country yet spend part of their life cycle in another country, is particularly difficult in the absence of a formal interception agreement. In the case of chum stocks originating from the Canadian portion of the Yukon River Basin, the basic management objective of optimal Canadian returns has not been realized. This is because of current interception levels in Alaska combined with the lack of a joint management plan. Canada has limited control over the magnitude of the chum salmon returns to the upper Yukon River watershed.

As a result of increased demand for chum salmon, the Department of Fisheries and Oceans has revised the relatively liberal fishing patterns that existed prior to 1982, when a six day per week open period and unlimited fishing effort were permitted. Since 1980, licences have been limited in both commercial and domestic fisheries, and openings are more dependent upon run strength. The management priority of the Department of Fisheries and Oceans has been, and continues to be, management for stock conservation, primarily for the maintenance of the native subsistence fishery.

In spite of these management actions, the escalation of commercial fall chum catches in both the Yukon Territory and Alaska is a cause for concern, especially in the absence of consistent escapement monitoring and common escapement goals. It is possible that increased catch levels have been made at the expense of spawning escapements.

2.0 SPAGHETTI TAGGING PROGRAM 1982-1983

2.1 Materials and Methods

2.1.1 Capture Techniques

Three methods were used to capture fish, as follows:

1. trapping by fishwheel (a device that traps fish in a rotating scoop assembly mounted on a raft);
2. gillnetting with small mesh gillnets;
3. seining;

These methods are described briefly below.

2.1.1.1 Fishwheel Design and Placements

In 1982, two fishwheels were constructed and positioned on the Yukon River 7 and 12 km, respectively, upstream from the Yukon-Alaska border. In 1983, three fishwheels were positioned 12, 15 and 18 km, respectively, above the border (Figure 1, Plates 1 and 2). These sites permitted tag application downstream from all Canadian fishing activities.

The fishwheels were of a two-basket variety, designed and prefabricated at the Department of Fisheries and Oceans shop in Whitehorse and later assembled on-site. The baskets and supporting structures were constructed with 3.8 cm x 8.9 cm milled lumber and covered with a stucco wire mesh measuring 5.1 x 5.1 cm. A high density polyethylene mesh material (L-70 Vexar) with a mesh opening of 4.5 x 4.5 cm was experimentally used in 1983. The largest fishwheel was capable of fishing an area 3 m deep x 3 m wide, whereas the smaller wheel could fish an area of 2.4 m deep x 2.4 m wide. Both wheels rotated on axles constructed from timbers

Plate 1: Fishwheel operating at Sheep Rock site on the Yukon River (18 km upstream of the international border).

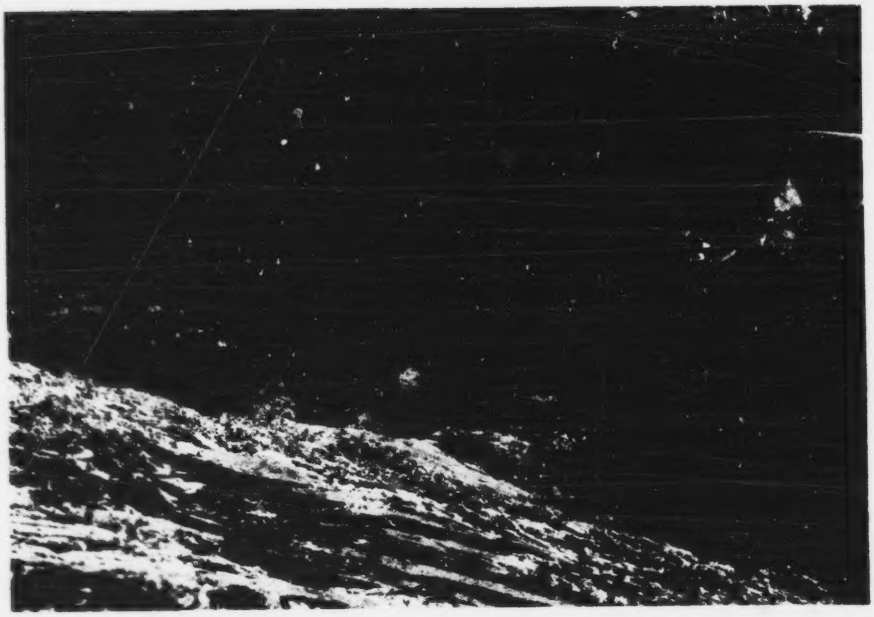

Plate 2: The Sheep Rock fishwheel was positioned at the upper limit of this eddy (single arrow). Double arrows indicate eddy line.

measuring 22 x 22 cm in diameter. Axle supports were designed for variable fishing depth. Approximately 0.9 m of depth adjustment was possible.

The substructure of each fishwheel consisted of two pontoon-type rafts framed with 3.8 cm x 19.0 cm milled lumber and decked with plywood. Deck dimensions of each pontoon were approximately 0.5 x 7.6 meters (20% longer for the larger wheel). The two pontoons were held apart by two 30.9 cm x 8.9 cm cross members which also served as walkways. These were located fore and aft of the fishwheel baskets. Floatation was provided by ten 200 litre (45 gallon) steel barrels filled with polyurethane foam. Five barrels were positioned under each pontoon. Live-boxes were constructed from plywood and aluminum grates (5.1 cm spacing between bars) which permitted a continuous flow of water over the captive fish (Plate 3). As the fishwheel rotated (one to six rpm), U-shaped slides built into each fishwheel basket deflected the fish into the live-boxes. Additional details of fishwheel design are presented in Appendix 2.

Prior to positioning the fishwheels, prospective sites (back eddies) were sounded using either a Furuno model 200 depth sounder or a five meter length of rebar[1]. This was done to determine if adequate fishing depths could be maintained throughout the typical low flow regime of late summer and fall. Once a suitable site was chosen, the fishwheel was positioned at the upstream limit of the eddy where the mainstream current was of sufficient force to turn the wheel. The fishwheel was secured in position with 0.95 cm diameter steel cables and several large polypropylene ropes. In addition, logs were used to hold the fishwheel out from and parallel to the shoreline. A lead (stucco wire and/or seine material) was placed obliquely from shore to the midpoint of the shoreward pontoon. Fish encountering this lead were directed towards the fishwheel.

The fishwheels were checked a minimum of three times daily. More frequent checks were made during peak migration in order to minimize overcrowding and

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[1] Rebar is a common term for steel rod used to reinforce concrete.

Plate 3: Live-captured chum in live-box located on side of fishwheel. Note the flow of well oxygenated water over the captive fish.

holding time. Repositioning of the fishwheel was frequently required due to fluctuating water levels.

2.1.1.2 Netting

Small mesh gillnets (10.2 cm - 11.4 cm stretched measure) were used as set nets or drift nets as alternative capture techniques during the 1982 field season. Set net dimensions were 30 m (length) x 2.2 m (depth), although the full length of the net was not always fished. Set nets were positioned in two small eddies located near the tagging site. A two-person tagging crew manned each net. Whenever a fish hit the net (this was evident from bobbing cork(s) along the corkline), the tagging crew pulled alongside the net in a small boat, removed the fish from the net, tagged, sampled (see section 2.1.5), and released the fish.

Drift nets (30 m in length x 2.4 m in depth) were fished along gently sloping gravel bars and in mainstem areas. Bar drifts were accomplished with one person walking the shoreline with a rope attached to one end of the net while two people attended the other end from the boat. Mainstem drifts were conducted with two people from a boat. Drifting with the current, these sets lasted from one to five minutes. Drift-net caught fish were immediately removed from the net, tagged, and released.

In 1982, beach seining was also conducted to live-capture chum salmon for tagging. Both juvenile and adult seines were used with the former measuring 30 m (length) x 1.7 m (depth) and a 0.6 cm mesh. The adult seine measured 61 m (length) x 6.1 m (depth) with a 7.6 cm mesh. The netting procedure involved one person positioned on shore and two people stationed in the attending boat. The seine net was drawn out into the current, drifted for approximately two minutes, looped into a hook shape, and pulled back into shore. The net was then drawn up on shore and the captive fish were tagged, sampled and released.

2.1.2 Application of Spaghetti Tags

The spaghetti tags used in this study consisted of consecutively numbered, fluorescent orange, hollow PVC tubing (size 13 - approximately 2.0 mm in diameter). Each tag had DFO identification and measured approximately 30 cm in length after it was clipped from the roll. These tags were obtained in 300 metre rolls from the Floy Tag Manufacturing Incorporation, Seattle, Washington.

Salmon captured by the techniques outlined in section 2.1.1 were transferred by dipnet to a tagging box (Plate 4). Spaghetti tags were applied with a 15 cm needle-like applicator which was inserted through the musculature beneath the dorsal fin (Plate 5). The ends of the spaghetti tag were knotted tightly together with a single overhand hitch. During the application of tags, biological sampling was also conducted as described in subsection 2.1.5. In total, the tagging and sampling procedure took from 25 seconds to one minute to complete.

2.1.3 Tag Recovery

Recaptures of tagged chum salmon were primarily made in commercial, subsistence, and domestic set gillnet fisheries. The mesh sizes used in these fisheries were variable, ranging from 11.4 cm to 20.3 cm (stretched measure). Additional tag recoveries were made from three commercial fishwheels. In 1982, the fishing period in both the commercial and domestic fisheries was restricted to three-five days per week, depending on the run strength. Fishing was permitted six days per week during the 1983 season. In both years, no time constraints were imposed on the native subsistence fishery.

To promote the return of tags recaptured in the commercial, domestic, native, and sport fisheries, lotteries were established. Ten $100.00 prizes were offered in 1982, while two $100.00 prizes were offered in 1983. Each tag or tag number returned with information regarding the date and location of capture was counted as an entry. Additional catch and tag recovery information from the commercial and subsistence fisheries was obtained from catch cards which were distributed to all fishermen. Posters advertising the draw were displayed in

Plate 4: Female chum positioned in tagging box prior to spaghetti tag application.

Plate 5: Spaghetti tag insertion into musculature below dorsal fin.

DFO offices in Whitehorse, Dawson City and Haines Junction, and in Post Offices and Wildlife Branch offices throughout the Yukon Territory. A list of draw winners was printed in two Whitehorse newspapers, the Whitehorse Star and the Yukon News.

Tag recoveries were made by field personnel during spawning ground surveys (section 2.1.4). Recapture techniques involved the use of previously described adult beach seines and/or gaffs.

2.1.4 Gross Escapement and Spawning Surveys

Escapement is defined as the number of fish which successfully migrate to spawning grounds. In this study, the overall escapement was determined from population estimates and recorded catch information with the following equation:

Escapement = total population estimate - total recorded catch.

The total recorded catch includes all Canadian commercial, domestic, and native subsistence catches in the upper Yukon River Basin.

Surveys of spawning chum were conducted in the Kluane River and a section of the mainstem Yukon River in 1982 and 1983. An aerial survey (DFO files and Foothills Pipeline Ltd. unpublished, 1982) of the upper Kluane River, conducted on October 14, 1982 identified 28 discrete survey stations. Ground searches of a number of these stations were conducted over the periods October 22 - 26, 1982 and October 18 - 21, 1983. Ground searches of the section of the mainstem Yukon River covered by the 1:250,000 Carmacks mapsheet (NTS) were conducted on the following dates: October 6-22, 1982; October 9-15 and October 22-25, 1983. In 1982, a field camp was established at the Yukon Territorial Campground at Minto. The focus of the 1982 survey was directed at chum spawning areas that were previously identified by Walker (1976). The 1983 surveys of the mainstem Yukon River were restricted to a number of ice-free areas identified during a winter survey conducted on March 8, 1983 (see section 2.1.9).

2.1.5 Biological Sampling

Baseline biological data was collected as part of an ongoing DFO sampling program. Chum salmon were sampled for size, sex, and age composition at the following locations:

1. the tagging sites;

2. Han Fisheries in Dawson City;

3. selected spawning grounds.

At the tagging sites, fork length was determined to the nearest centimeter with a meter stick attached to the tagging box. Sex was determined by visual examination of external morphological characteristics or expelled sex products. Two scales were removed from the preferred area located two rows above the lateral line along an imaginary line extending from the anterior edge of the anal fin to the posterior margin of the dorsal fin.

In addition to the sampling procedures outlined above, a random sample of the commercial catch was measured for post-orbital hypural length using a one-metre hypural stick. Weight was determined with a 60 pound capacity Detecto dial scale (to the nearest ounce) and later converted into kilograms. A total of five scales were removed from each fish for age analysis.

Chum sampled on the spawning grounds were measured for fork and hypural length. Carcasses were dissected in order to examine the presence of retained sex products. Ten scales were removed for age analysis. This number of scales was necessary because of the high rate of scale resorption common to spawning populations.

In all cases, scale samples were cleaned and stored on numbered gum cards. Scale impressions were made on acetate slides using a Model C Carver scale press located in the DFO office, Whitehorse. Ages were then determined using standard techniques.

2.1.6 Population Estimates

Population estimates were calculated from the tag and recapture information and commercial catch statistics collected downstream of the first major tributary (Stewart River). Catch and tag recovery information from below the Stewart River is the most reliable information available. Commercial fishing activity is most constant in the Dawson City area and daily catch records were checked and collected on a weekly basis by fisheries personnel. Catch information downstream of the Stewart River also reduces the statistical bias of retrieving tags from an unknown sample size. Tag returns from other areas were useful in determining catch distribution. The calculated population estimates represent the total number of chum migrating into the upper Yukon River Basin.

Populations estimates were determined with the Adjusted Petersen Estimate (APE), which gives an unbiased estimate in most situations (Ricker, 1975), and the Schaefer Estimate (SE) for stratified populations, which stratifies the time of marking and recovery into a series of units, each partially distinct from adjacent units. The SE reduces the bias of the standard Petersen estimate if the original marking and sampling for recoveries are selective (Ricker, 1975).

The adjusted Petersen and Schaefer formulae are as follows:

Adjusted Petersen Estimate

$$N = \frac{(M + 1)(C + 1)}{R + 1}$$

Where:

N = size of population

M = number of fish marked

C = total commercial catch examined for tags

R = number of recaptured tags in the sample

Schaefer Estimate

$$N = \Sigma N_{ij} = \Sigma \left(R_{ij} = \frac{M_i}{R_i}\frac{C_j}{R_j}\right)$$

Where:

N = size of population

M_i = number of fish tagged in ith period of tagging

C_j = number of fish examined in the jth period of recovery

C = ΣC_j, total number examined

Rij = number of fish marked in ith tagging period which are recaptured in the jth recovery period

Ri = total recapture of fish tagged in the ith period

Rj = total recaptured during the jth period

The 95% confidence limits (r) were determined for the number of recaptures (R). For R values less than 50, the confidence limits were determined from a table presented in Ricker (1975; page 343). Pearson's formula was used for R values greater than 50. Pearson's formula is as follows:

$$95\% \text{ confidence limits} = x + 1.92 \pm 1.96 \sqrt{x + 1.0} \quad \text{where } x = R$$

The lower and upper limits for the r values were then applied to the Adjusted Petersen formula.

2.1.7 Exploitation Rates

Exploitation rates were determined for the Dawson area commercial fishery from tag returns below the Stewart River. The total exploitation rate was determined from tag returns from all sources. Adjustments were not made for tagging mortality or tag loss, as these were not considered significant factors. Exploitation rates were determined with the following formula:

$$\text{Exploitation Rate} = \frac{\text{number of tags returned}}{\text{number of tags applied}} \times 100\%$$

Weekly exploitation rates (for 1982) were determined for the Dawson area commercial fishery with the following formula:

$$\text{Weekly exploitation rate in Dawson area commercial fishery} = \frac{\text{number of salmon caught commercially}}{\text{estimated number of fish available for capture as determined by the Schaefer estimate}} \times 100\%$$

2.1.8 Migration Rates

Migration rates were determined from spaghetti tag recovery information with the following formula:

$$\text{Migration Rate} = \frac{\text{distance travelled (km)}}{\text{elapsed time (days)}}$$

The sum of the migration rates were averaged to give a mean rate. Migration rates were calculated in $\mathrm{km.day}^{-1}$ rather than $\mathrm{km.h}^{-1}$ because the precise time of the recaptures was not known.

2.1.9 Winter Survey of Open Water Areas

In winter, open water areas in rivers and streams can occur as a result of warmer groundwater flowing from springs. Open areas that persist throughout late winter are indicative of significant groundwater intrusion. A survey of spring-fed open water areas of the mainstem Yukon, White, Donjek and Kluane Rivers was conducted by fixed-wing aircraft on March 8, 1983. Observers marked all ice-free areas on 1:50,000 (if available) or 1:250,000 scale maps. The objectives of this survey were as follows:

1. to identify ice-free areas;
2. to classify ice-free areas as being current related or from groundwater intrusion;
3. to determine if a relationship exists between groundwater areas and chum spawning locations.

2.2 Results and Discussion

2.2.1 Tag Application and Method Limitations

In 1982, 1,082 chum salmon were tagged with spaghetti tags between August 8 and October 4; 797 were captured by fishwheel and 285 were captured with small mesh gillnets set near shore. Additional chum were successfully live-captured by drift netting and beach seining techniques, but these fish were not tagged. These netting and seining techniques were discontinued early in the program because of high gear loss. The spaghetti tagging program was terminated on October 4 because of continued ice buildup which prevented the fishwheels from turning and because declining fishwheel and commercial catches prior to this date indicated that the peak of the chum run had passed.

In 1983, 3,176 chum salmon were captured by fishwheel and tagged with spaghetti tags between July 18 and October 2. The tagging program was terminated on October 2 because of continued ice buildup on the fishwheels (Plate 6), declining catches, poor quality of the fish, and reduced commercial fishing activity.

The fishwheel trapping and the gillnetting techniques were efficient methods of live-capturing chum salmon. Chum were vulnerable to shore-based gillnetting and seining because they migrated at shallow water depths close to the river's edge. The fishwheels were more effective than gillnetting and seining in terms of maintenance and manpower costs. The major difficulties encountered in fishwheel operation involved positioning the fishwheels and repairing structural damage. During periods of declining discharge, fishwheels had to be continually repositioned farther from the shoreline to areas where fishing depth and current flow were adequate. This repositioning was most difficult during low flow periods. During peak flow conditions, floating debris (logs, tree limbs, etc.) repeatedly damaged the fishwheel baskets.

The Vexar mesh material used experimentally to cover the fishwheel baskets functioned effectively for the early part of the season. The most notable characteristic of this material was its low operational noise. The limitations of this material became evident during cooler weather when the mesh continually broke.

The set gillnets fished well, particularly during the peak of the chum run. The 10.2 - 11.4 cm mesh size was very effective in entangling the chum by mouth parts. The efficiency of the set nets was lowest during high water levels when debris (leaves, sticks, etc.) filled the mesh.

Plate 6: Ice buildup on the fishwheel in early October.

2.2.3 Tag Recovery, Exploitation Rates and Catch Information

In 1982, 223 of the 1,082 spaghetti tags applied were recovered in the commercial fishery below the Stewart River. An additional 60 tags were recovered in the commercial and subsistence fisheries in the upper Yukon and two tags were recovered on the spawning grounds. Several other tags were observed during spawning ground surveys, but the survey crews were unable to recover them.

In 1983, 665 of the 3,176 spaghetti tags applied were recovered in the commercial fishery below the Stewart River. An additional 87 tags were recovered in commercial and subsistence fisheries in the upper Yukon. Forty tags were recovered in spawning areas on the Donjek and Kluane Rivers and seven additional tags were observed but not recovered. Ten tags were recovered in mainstem (Yukon River) spawning areas in the Minto area and seven additional tags were observed.

The chum exploitation rates in the Dawson area commercial fishery in 1982 and 1983 were as follows:

1982: $\frac{\text{223 tags recaptured}}{\text{1,082 tags applied}} \times 100\% = 20.6\%$

Weekly chum exploitation rates ranged from a low of 18.7% to a high of 29.7% (Figure 3).

1983: $\frac{\text{665 tags recaptured}}{\text{3,176 tags applied}} \times 100\% = 20.9\%$

Weekly chum exploitation rates were not determined in 1983 because a Schaefer Estimate was not determined.

The overall exploitation rates of chum in the upper Yukon Basin in 1982 and 1983 were as follows:

1982: $\frac{\text{283 tags recaptured}}{\text{1,082 tags applied}} \times 100\% = 26.2\%$

1983: $\frac{\text{752 tags recaptured}}{\text{3,176 tags applied}} \times 100\% = 23.7\%$

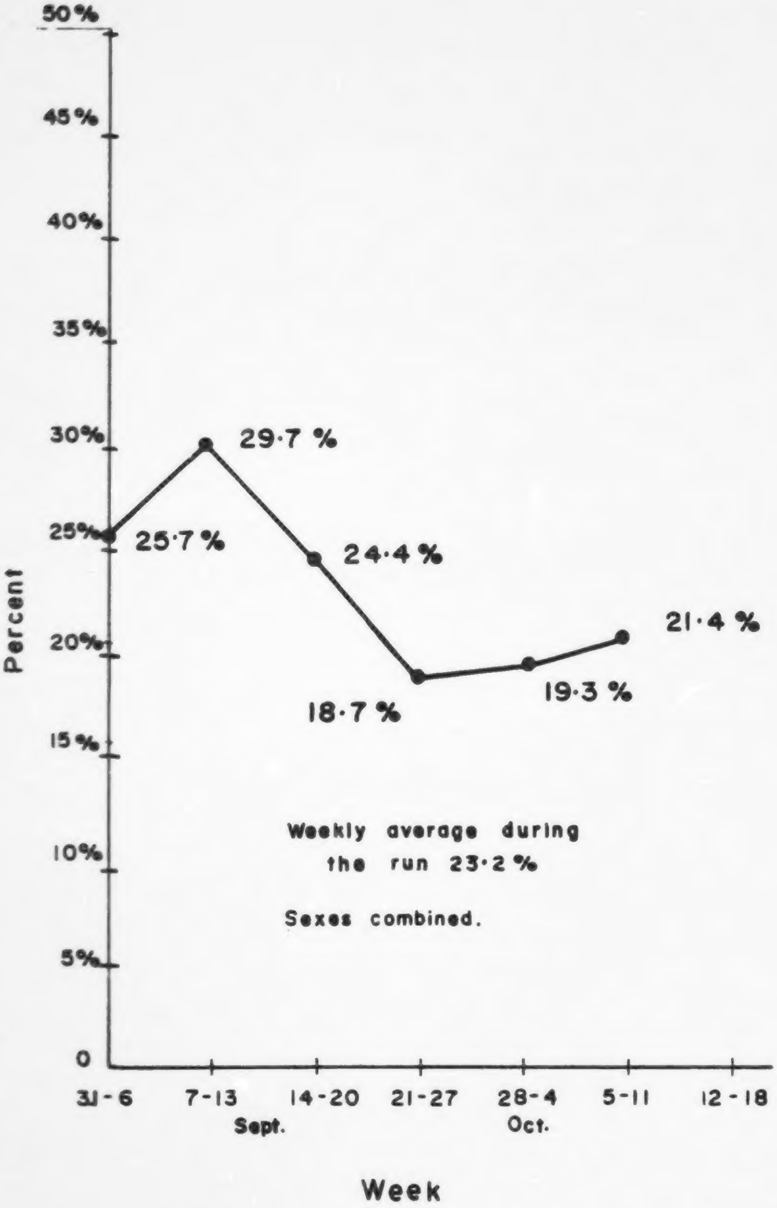


Figure 3 Weekly chum exploitation rate in Dawson area commercial fishery 1982

The 1982 and 1983 exploitation rates in the commercial fishery in the Yukon River below the Stewart-Yukon confluence were similar. Because the 1983 commercial catch (24,812; preliminary calculation) in this area was much greater than the 1982 catch (10,314 preliminary calculation), the fact that the exploitation rate remained nearly the same indicates that the 1983 chum run was much larger than in 1982.

The 1982 and 1983 exploitation rates were similar to values recorded in tagging programs conducted in 1973 (Sweitzer, 1974) and 1974 (Brock, 1976). For the 1973 study, in which Petersen disc tags were used, an exploitation rate of 17.6% was reported; for 1974, when spaghetti tags were used, the exploitation rate was 19.8%. These rates are much lower than a rate of 57.6% determined in 1978 (Johnston, in prep.) on the basis of a Petersen disc tagging program. This high rate may have been caused, at least partly, by an increased catchability of the tagged fish, which is known to be caused by the entanglement of the disc in the gillnet.

2.2.3 Population Estimates

Chum population estimates were determined from the following preliminary commercial catch and tag return information from the area of the Yukon River downstream of the confluence of the Stewart River:

Year	Number of Fish Tagged	Commercial Catch	Number of Tags Returned
1982	1,082	10,314	223
1983	3,176	24,812	665

The population estimates were calculated as follows:

I. Schaefer Estimate: 1982

Using combined male and female

$$N = \Sigma Nij = \Sigma (Rij \times \frac{Mi}{Ri} \times \frac{Cj}{Rj})$$

N = 47,049

II. Adjusted Petersen Estimate: 1982

Using combined male and female

i) $N = \frac{(M + 1)(C + 1)}{(R + 1)}$

$N = \frac{(1,082 + 1)(10,314 + 1)}{(57 + 1)}$

N = 49,871

ii) 95% confidence limits for R
(R = 223)

Lower limit: 254.25
Upper limit: 195.59

iii) 95% confidence limits for N

Lower limit: N = 43,938
Upper limit: N = 56,115

III. Adjusted Petersen Estimate: 1983

Using combined male and female

i) $N = \frac{(M + 1)(C + 1)}{(R + 1)}$

$N = \frac{(3,176 + 1)(24,812 + 1)}{(665 + 1)}$

N = 118,365

ii) 95% confidence limits for R
(x = 665)

Lower limit: r = 717.52
Upper limit: r = 616.32

iii) 95% confidence limits for N

Lower limit: N = 109,866
Upper limit: N = 127,906

The Schaefer estimate was not calculated in 1983 because of time constraints and the similarity between estimates determined with the Schaefer and Adjusted Petersen Estimates in 1982.

The 1982 population estimates determined with the Schaefer and Adjusted Petersen Estimates were similar, although the Adjusted Petersen Estimate of 48,871 chum was slightly higher than an estimate of 47,049 determined with the Schaefer Estimate. The 1983 population estimate of 118,365 chum was the largest population estimate recorded for the upper Yukon River Basin. The increased run strength in 1983, which was evident from a high commercial catch and a strong return to spawning areas, appeared to represent a dominant cycle year based on a four-year cycle. Peak chum returns were observed during previous cycle year returns in 1975 and 1979 (Walker, 1976; DFO files). The chum return in 1983 was influenced to a yet undetermined extent by a 10-day closure in the Alaskan commercial fishery early in the chum run.

In summary, the results of the 1982 and 1983 spaghetti-tagging program included two main observations: the esimated population sizes for 1982 and 1983 were substantially higher than estimates determined in previous tag-recovery programs; and the mark-recapture techniques used to determine the population estimates were an adequate means of assessing the chum return to Canadian portions of the upper Yukon River Basin.

2.2.4 Biological Sampling

Totals of 1,417 and 4,025 chum were sampled in 1982 and 1983, respectively (Table 4). Biological data obtained in relation to age composition, sex ratios, length frequency and weight are described in the following sections.

2.2.4.1 Age Composition

The ages of all chum sampled ranged from three to six years of age (Tables 5 and 6). Four-year old fish were predominant, as shown below:

Sample Source	Proportion (%) of Four Year Olds 1982	1983
Tagging site	72.1	93.5
Han Fishery	61.5	95.3
Spawning grounds	56.0	87.5
Tag returns	72.8	91.5

TABLE 4. Sex composition of Yukon River chum salmon in 1982 and 1983.

Location	Percent Male		Total Sample Size	
	1982	1983	1982	1983
Fishwheels	49.1	46.2	784	3176
Gillnet tagged (1982)	58.2	-	285	-
Han Fishery	57.3	56.6	431	670
Spawning Grounds	41.2	52.5	245	179
Tag Returns	76.1	67.0	285	694

TABLE 5. Comparison of the age and sex composition of chum salmon from the various sampling locations in 1982.

A) TAGGING SITE

AGE	TOTAL	MALE		FEMALE		COMBINED
	N	NUMBER	%	NUMBER	%	
3	155	62	7.6	93	11.5	19.1
4	584	313	38.6	271	33.5	72.1
5	71	36	4.5	35	4.3	8.8
TOTAL	810	411	50.7	399	49.3	100.0

B) COMMERCIAL FISHERY

AGE	TOTAL	MALE		FEMALE		COMBINED
	N	NUMBER	%	NUMBER	%	
3	23	9	2.3	14	3.7	6.0
4	235	139	36.4	96	25.1	61.5
5	124	71	18.6	53	13.9	32.5
TOTAL	382	219	57.3	163	42.7	100.0

C) SPAWNING GROUNDS

AGE	TOTAL	MALE		FEMALE		COMBINED
	N	NUMBER	%	NUMBER	%	
3	11	4	1.8	7	3.1	4.9
4	126	48	21.3	78	34.7	56.0
5	88	39	17.3	49	21.8	39.1
TOTAL	225	91	40.4	134	59.6	100.0

D) TAG RETURNS

AGE	TOTAL	MALE		FEMALE		COMBINED
	N	NUMBER	%	NUMBER	%	
3	29	17	9.1	12	6.4	15.5
4	136	109	58.3	27	14.5	72.8
5	22	18	9.6	4	2.1	11.7
TOTAL	187	144	77.0	43	23.0	100.0

TABLE 6. Comparison of the age and sex composition of chum salmon from the various sampling locations in 1983.

A) TAGGING SITE

	TOTAL	MALE		FEMALE		COMBINED
AGE	N	NUMBER	%	NUMBER	%	
3	42	13	0.6	29	1.2	1.8
4	2164	960	41.5	1204	52.0	93.5
5	106	65	2.8	41	1.8	4.6
6	1	1	0.1	0	0.0	0.1
Total	2313	1039	45.0	1274	55.0	100.0

B) COMMERCIAL FISHERY

	TOTAL	MALE		FEMALE		COMBINED
AGE	N	NUMBER	%	NUMBER	%	
3	4	2	0.4	2	0.4	0.8
4	536	272	48.3	264	47.0	95.3
5	22	16	2.8	6	1.1	3.9
6	0	0	0.0	0	0.0	0.0
Total	562	290	51.5	272	48.5	100.0

C) SPAWNING GROUNDS

	TOTAL	MALE		FEMALE		COMBINED
AGE	N	NUMBER	%	NUMBER	%	
3	1	1	0.6	0	0.0	0.6
4	133	63	41.4	70	46.1	87.5
5	18	10	6.6	8	5.3	11.9
6	0	0	0.0	0	0.0	0.0
Total	152	74	48.6	78	51.4	100.0

D) TAG RETURNS COMMERCIAL FISHERY

	TOTAL	MALE		FEMALE		COMBINED
AGE	N	NUMBER	%	NUMBER	%	
3	9	3	0.6	6	1.2	1.8
4	452	295	59.7	157	31.8	91.5
5	32	23	4.7	9	1.8	6.5
6	1	1	0.2	0	0.0	0.2
TOTAL	494	322	65.2	172	34.8	100.0

The age composition of chum sampled in previous tagging programs also ranged from three to six years of age, although different age groups were more predominant. Brock (1976) noted that 61.8% of the tagged chum were three years of age. Sweitzer (1974) recorded the following age classes:

Age Class (citing Sweitzer 1974)	Percent Composition	
	Yukon River	White River
IV	54.7	22.1
V	42.3	61.9
VI	2.9	15.9

The variation in age classification is probably attributable more to the readability of the scale samples than to age differences between years or sample areas. An age analysis of a subsample (n=100) of the scale samples collected by Brock indicated that the age of the scales was 86.6% four years of age (Etherton, personal communication), which suggests that because of the resorption of the outer annulus, the 1976 analyses could have erred through the omission or addition of a year's growth during scale reading.

2.2.4.2 Sex Ratios

The proportions of male and female chum at the various sampling sites are presented in Table 4. Of the total number of chum that were tagged in 1982 and in 1983, male and female proportions were similar in both years; however, in the 1982 and 1983 samples from the tag returns and the Han Fisheries catch, the incidence of males was higher, and in both years the highest incidence of males occurred in the tag return sample. This high incidence of males in the tag return and Hans Fisheries samples was attributed to two factors: one, that these samples were collected by gillnet; and two, that because of their more developed mouth parts, male chum are more susceptible than females to entanglement in gillnets. The selectivity of gillnets for male chum was also evident in the gillnet samples for the 1982 tagging program. No sex selectivity was evident in fishwheel catches.

2.2.4.3 Length Frequencies

The 1982 length frequencies for male and female chum are illustrated in Figures 4 and 5. For the fishwheel samples (which include the small gillnet sample), the median fork length of male chum was 694.4 mm. Median fork lengths for the tag return and spawning ground samples were within the same fork length interval (690-699 mm) as the fishwheel catch, but for the Han Fisheries sample median fork length was shorter (685.5 mm) (Figure 4). The median fork length of female chum in 1982 was as follows: 625.5 mm (tagging site); 632.8 mm (tag returns); 645.5 mm (Han Fisheries); and 620.2 mm on the spawning grounds (Figure 5). The median fork length of females at the Han Fisheries and in the tag return sample was slightly larger than in the other samples.

Length frequencies for the 1983 samples are presented in Figures 6 and 7. Male chum sampled at the Han Fisheries (median fork length 691.2 mm) and on the spawning grounds (median fork length 697.1 mm) were larger than males sampled at the fishwheels (662.5 mm median fork length) (Figure 6). The male tag return sample (674.4 mm) was closest to the fishwheel catch in length. Female chum at the tagging site had a shorter median fork length value (610.3 mm) than at the other sampling sites (Figure 7). The Han Fisheries sample had the largest median fork length value (650.4 mm).

2.2.4.4 Weight

The average chum weight by age class at the Han Fishery in 1982 is presented in Figure 8. Within each age class, male chum were approximately 0.5 kg heavier than female chum. For both sexes, weight increased in direct proportion to age in 1982 as well as in 1983 (Figure 9); and the mean weight of both three and four-year old chum was heavier in 1983 than in 1982.

The average length frequencies for the various sampling sites for 1982 and 1983 are presented in Figures 10 and 11, respectively. Generally, male chum were larger than female chum, and for both sexes, fish in older age classes were larger

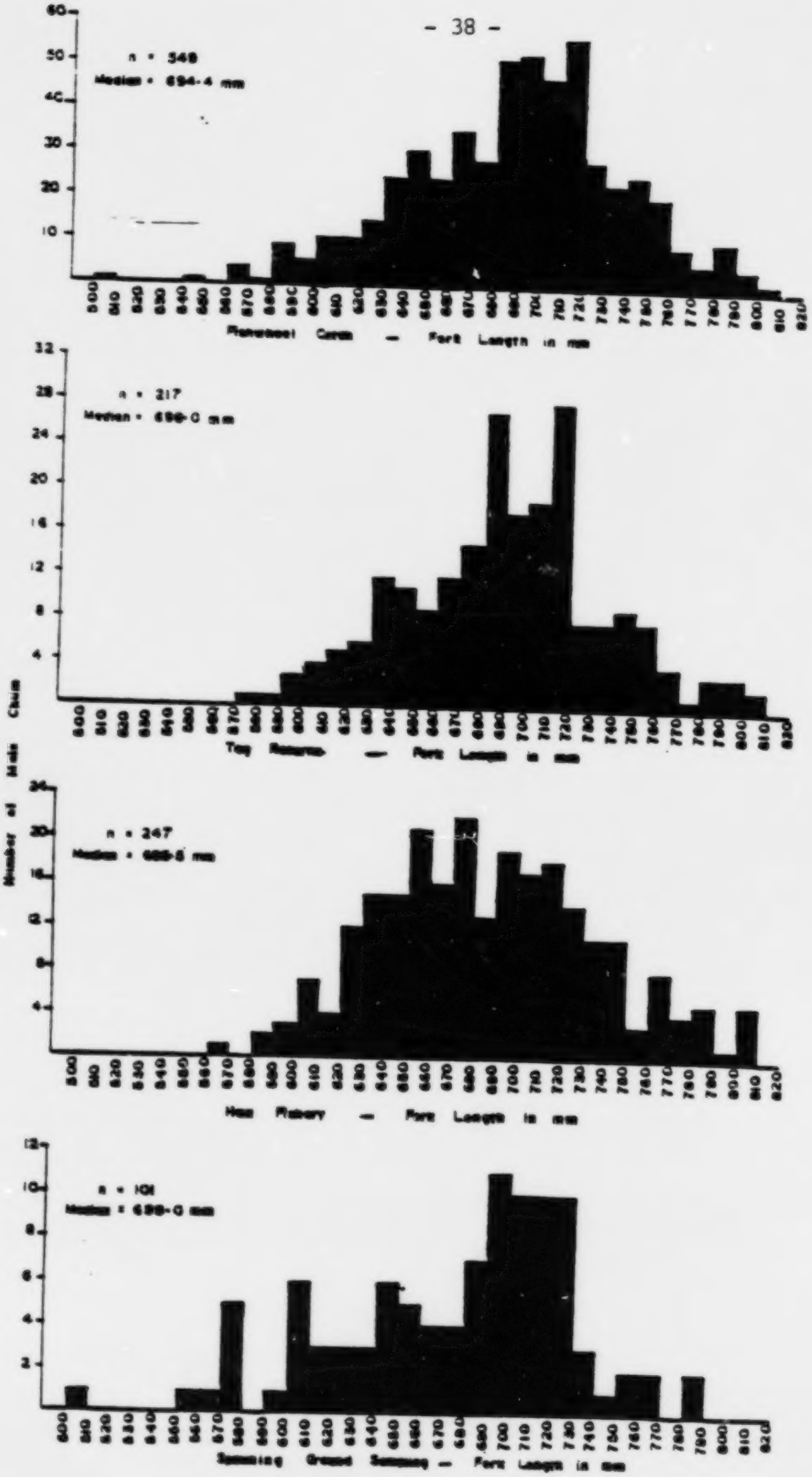


Figure 4 Length frequency of male chum salmon sampled in 1982

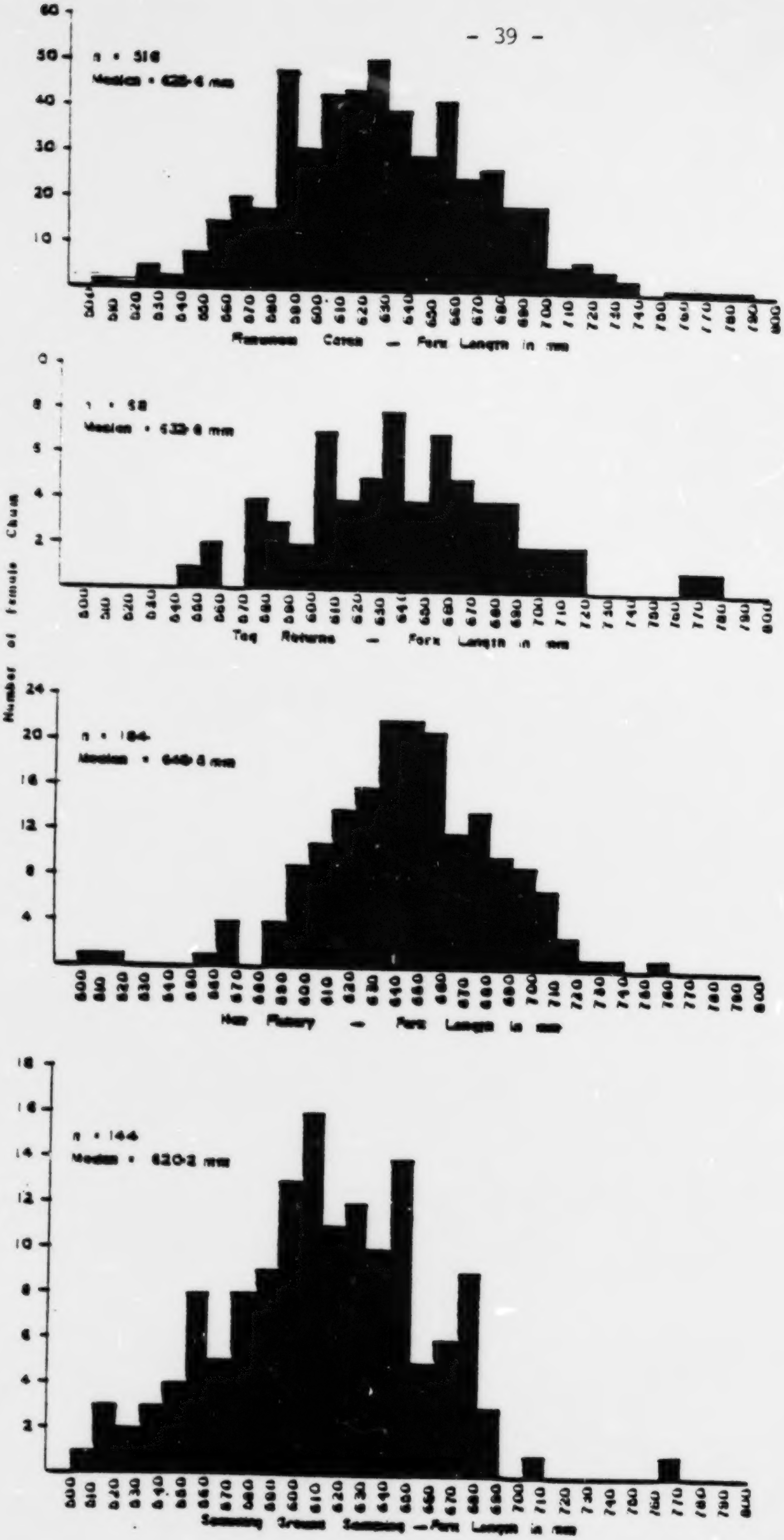


Figure 5 Length frequency of female chum salmon sampled in 1982

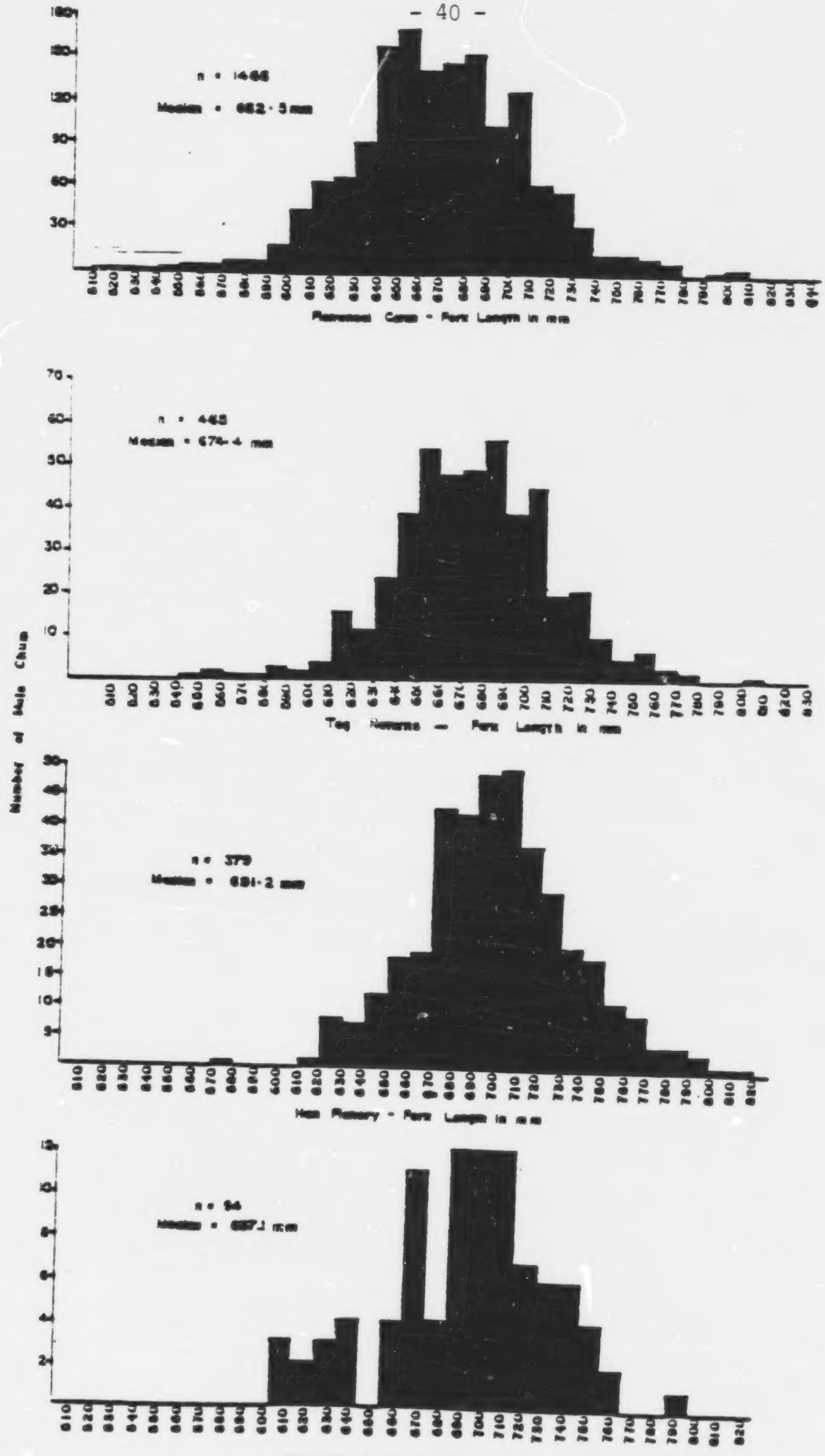


Figure 6 Length frequency of male chum salmon sampled in 1983

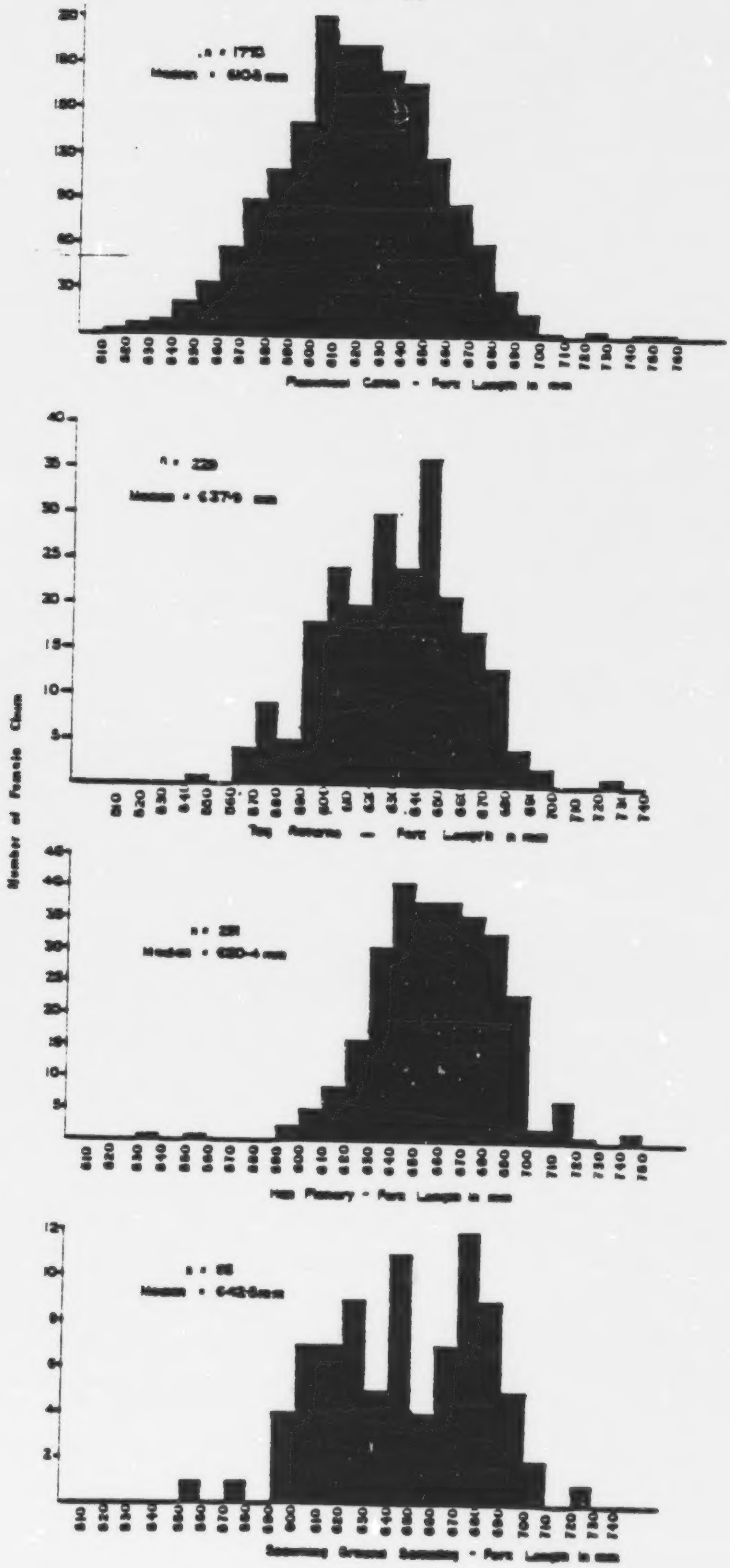


Figure 7 Length frequency of female chum salmon sampled in 1983

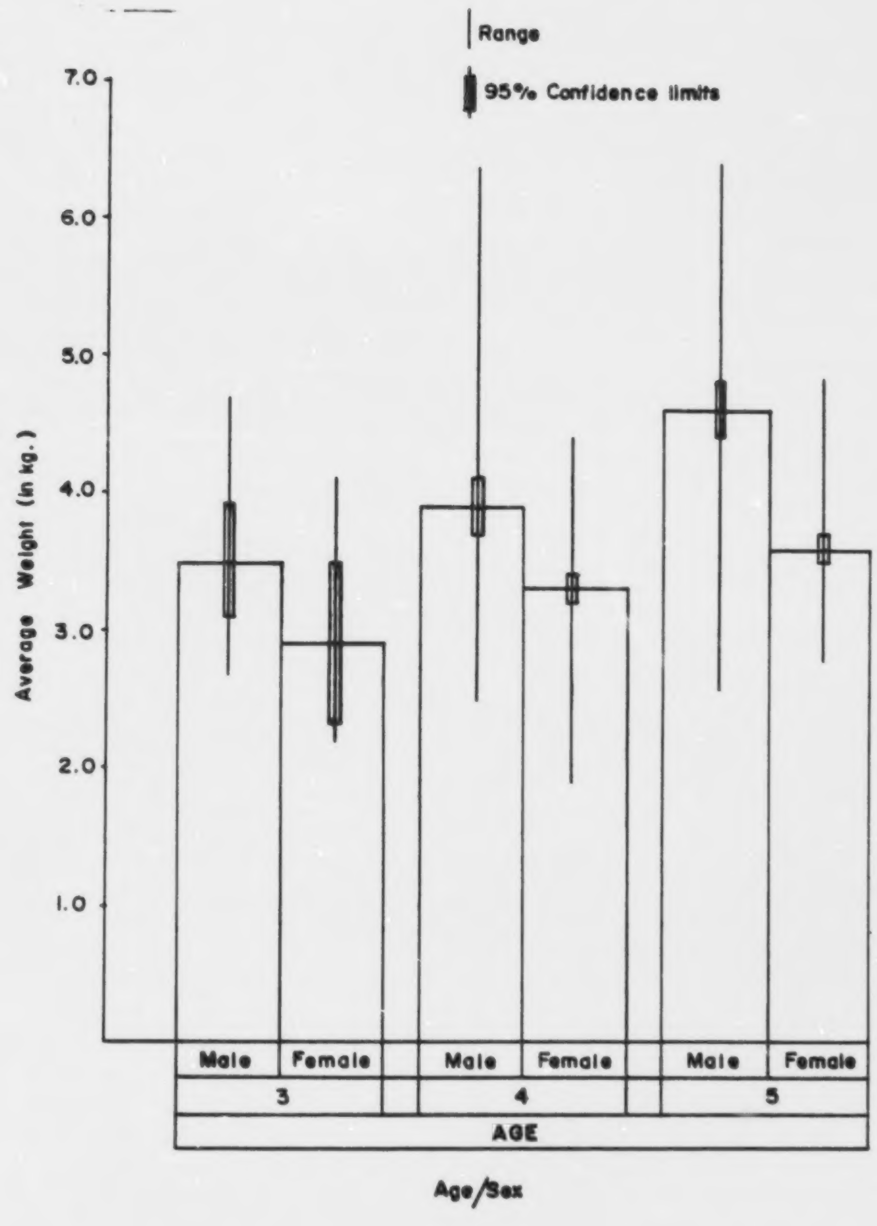


Figure 8 Average weight by age class of chum salmon sampled at the Han fishery in 1982

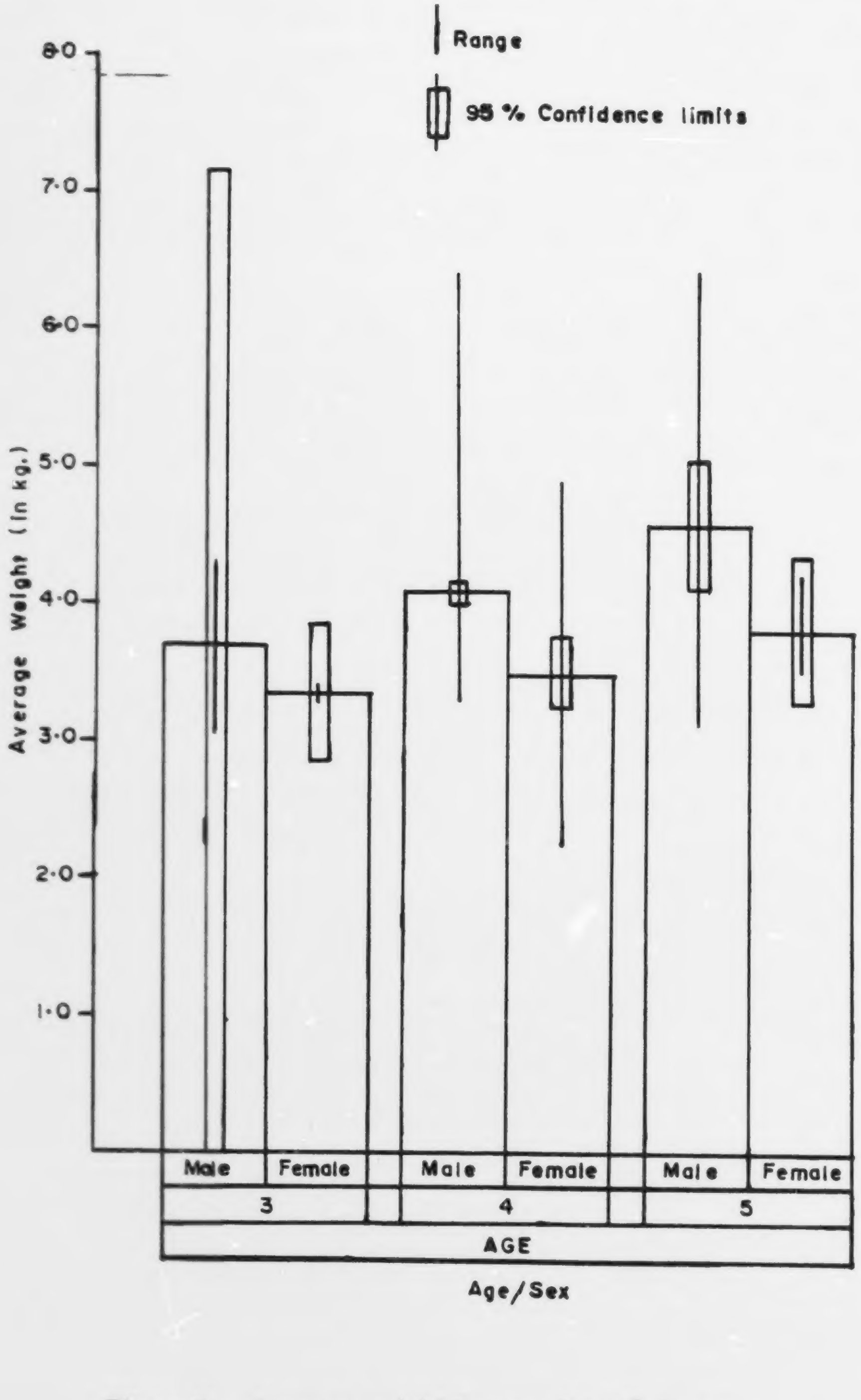


Figure 9 Average weight by age class of chum salmon sampled at the Han fishery in 1983

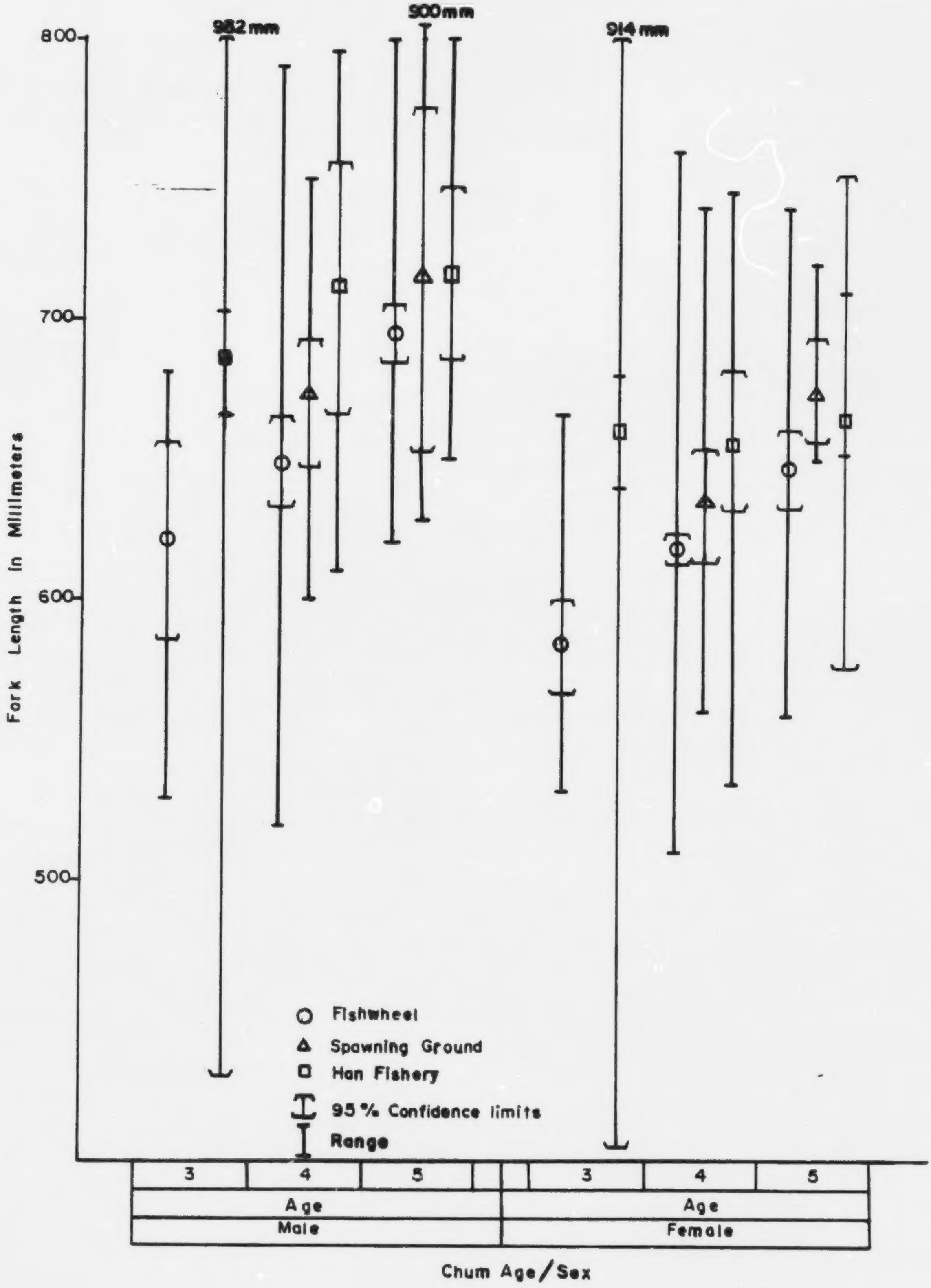


Figure 10 Length-age relationship by sex of chum salmon sampled in 1982 (mean fork lengths are indicated by appropriate sample symbol)

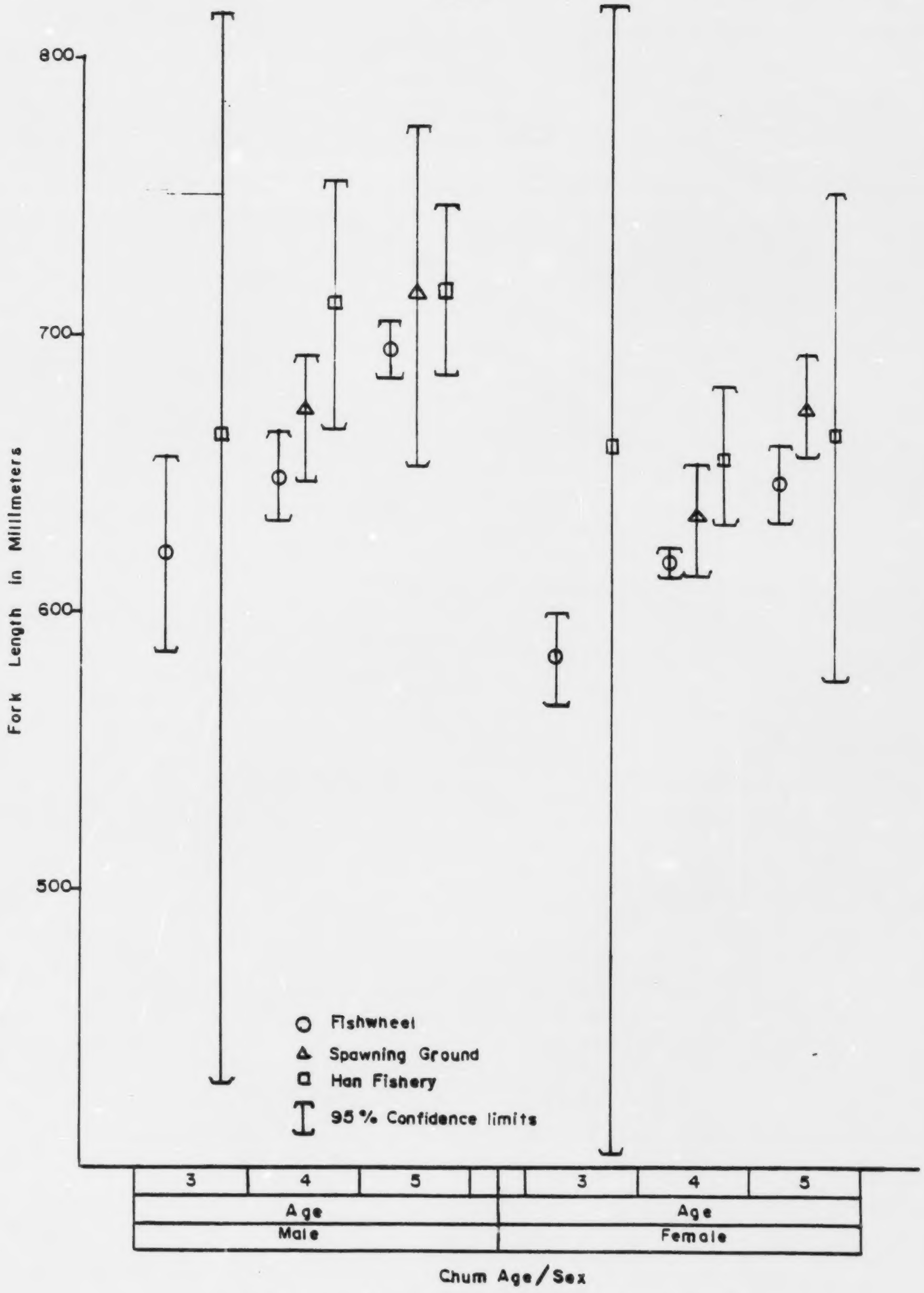


Figure 11 Length-age relationship by sex of chum salmon sampled in 1983 (mean fork lengths are indicated by appropriate sample symbol)

than the younger fish. The Han Fisheries catch gear apparently is selective for the larger fish within each age class.

2.2.5 Winter Open Water Areas

The results of the winter aerial survey of springfed open water area sites on the mainstem Yukon, White, Donjek, and Kluane Rivers were as follows:

Mainstem Yukon:

- Lake LaBerge to Carmacks: 26 open water sites were identified, all of which appeared to be current-related;
- Carmacks to below Fort Selkirk: 42 open water sites, most of which were not current-related, were located in side channel areas where groundwater discharge was apparent (Figures 12 and 13);
- Area below Fort Selkirk to White River: 22 open water sites were identified, most of which appeared to be current-related, but a few sites were located in side channel areas where groundwater discharge was suspected.

White River:

- 25 open water sites were identified, most of which appeared to be current-related, but because of the braided nature of this river, it was difficult to distinguish between current-related and groundwater discharge areas.

Donjek River:

- 25 open water sites were identified, most of which appeared to be current-related, although groundwater discharge was suspected in a few areas.

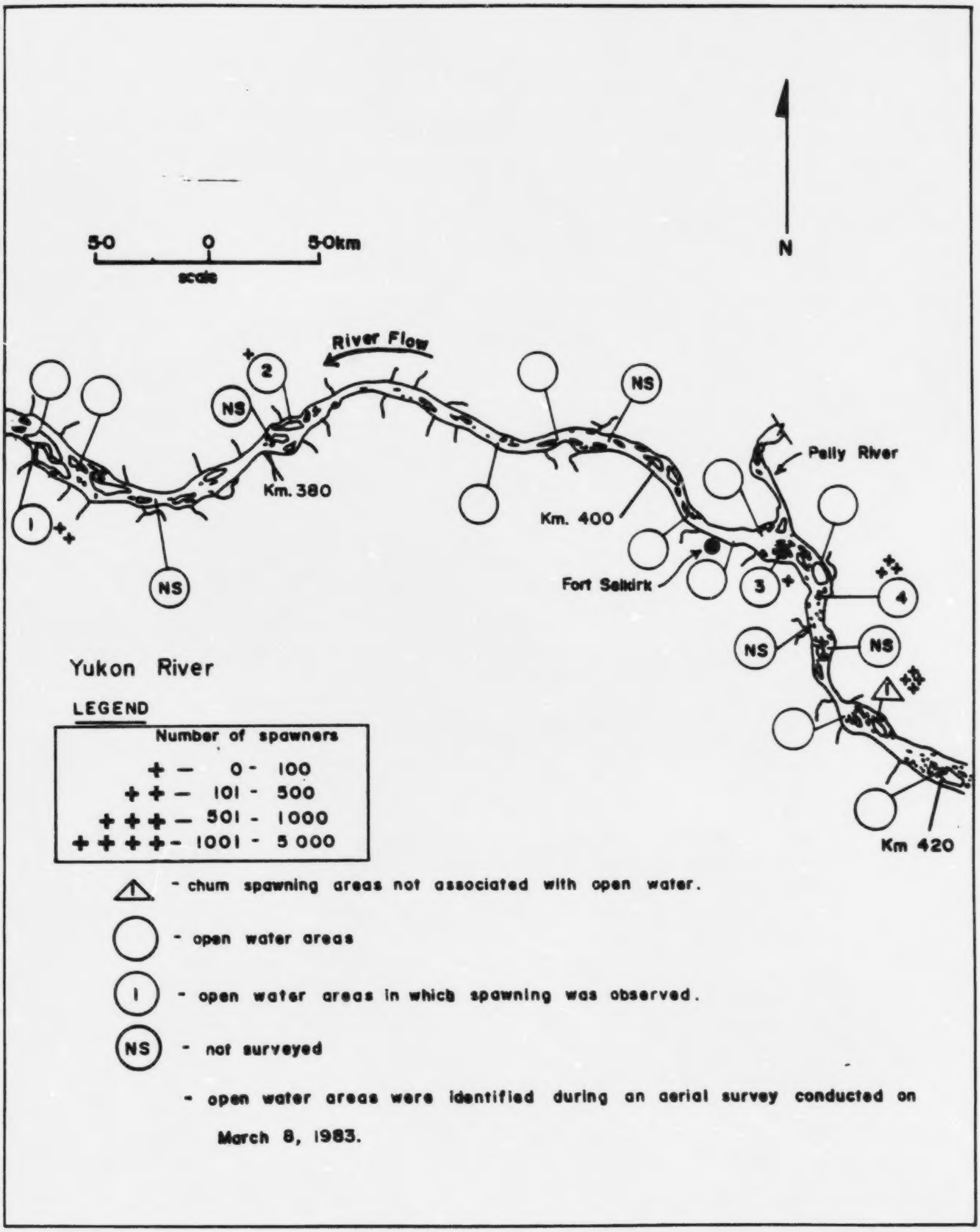

5-0
0
5-0km
scale
N
River Flow
2
NS
Km. 380
1
NS
NS
Km. 400
Pelly River
Fort Selkirk
3
4
NS
NS
Km 420
Yukon River
LEGEND
Number of spawners
+ — 0 - 100
+ + — 101 - 500
+ + + — 501 - 1000
+ + + + - 1001 - 5 000
- chum spawning areas not associated with open water.
- open water areas
- open water areas in which spawning was observed.
NS - not surveyed
- open water areas were identified during an aerial survey conducted on March 8, 1983.

Figure 12 Chum spawning areas associated with open water areas in the mainstem Yukon above Fort Selkirk

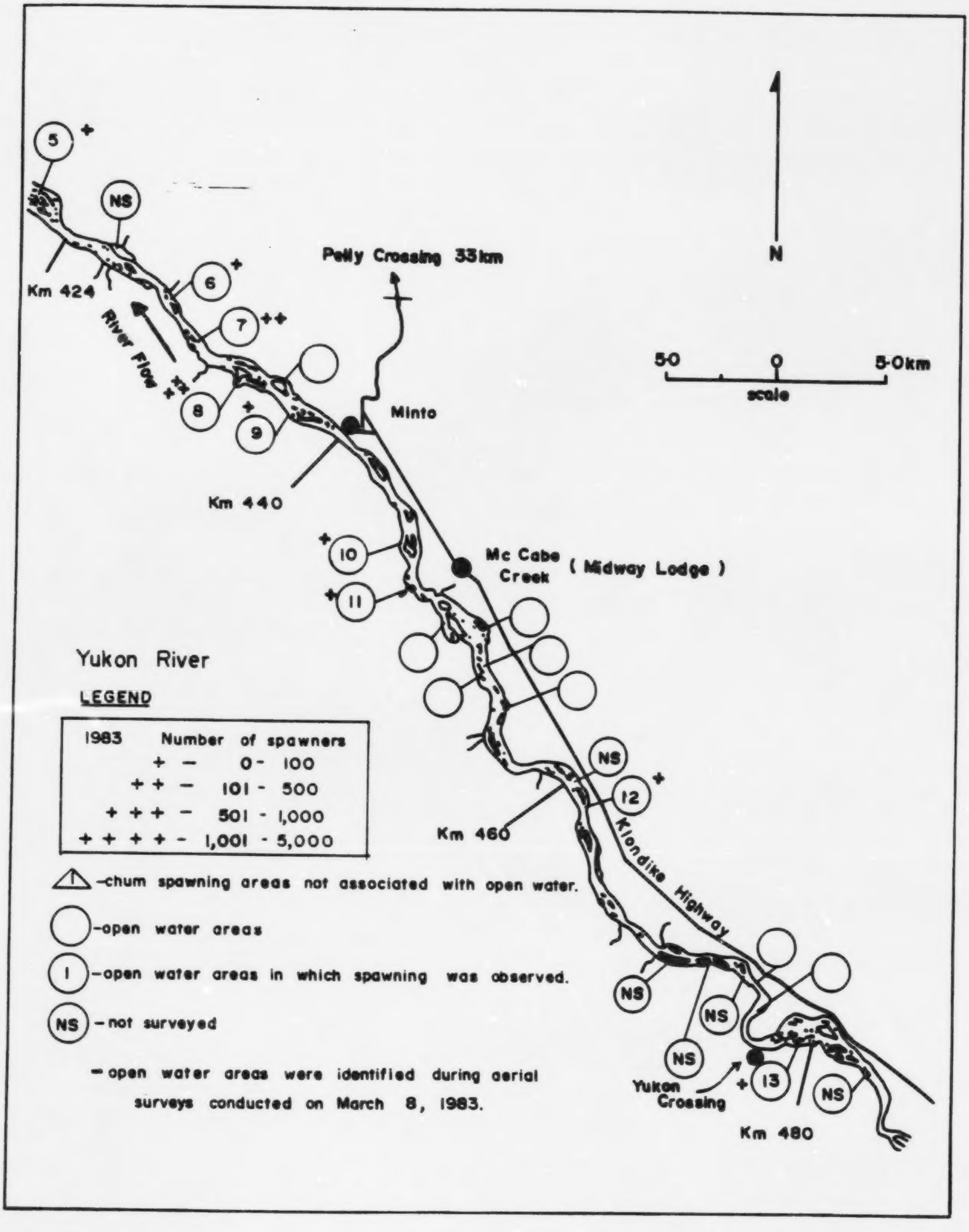

5 +
NS
Km 424
6 +
7 ++
River Flow
8
9 +
Pelly Crossing 33km
Minto
Km 440
N
5·0
0
5·0km
scale
10 +
11 +
Mc Cabe Creek
(Midway Lodge)
Yukon River
LEGEND
1983 Number of spawners
+ - 0 - 100
+ + - 101 - 500
+ + + - 501 - 1,000
+ + + + - 1,001 - 5,000
-chum spawning areas not associated with open water.
-open water areas
1 -open water areas in which spawning was observed.
NS - not surveyed
- open water areas were identified during aerial surveys conducted on March 8, 1983.
NS
12 +
Km 460
Klondike Highway
NS
NS
NS
Yukon Crossing
+ 13
NS
Km 480

Figure 13 Chum spawning areas associated with open water areas in the mainstem Yukon below Fort Selkirk

Kluane River:

- eight open water sites were identified, and most were suspected to be groundwater related.

From this survey, it was apparent that many of the ice-free areas resulted from groundwater intrusion (Hodge, personal communication). As indicated previously, the warmer water temperatures associated with groundwater discharge was seen to prevent solid ice formation in many shallow side channel areas that would otherwise have been frozen (Plate 7). The locations of these open water areas on the mainstem Yukon (below Fort Selkirk to Yukon Crossing) and on the upper Kluane River were the focus of the 1983 spawning ground surveys, to determine if chum salmon preferred these areas.

2.2.6 Gross Escapement and Spawning Surveys

In 1982, chum escapement totalled 31,350, based on the Schaefer Population Estimate of 47,049 (sexes combined) and a total commercial, domestic, and native subsistence catch of 15,691. The 1983 escapement of 92,306, which was based on the Adjusted Petersen Estimate of 118,365 (sexes combined) and a total commercial, domestic and subsistence catch of 26,059, was thought to be conservative since chum migration continued after the tagging program was completed on October 2. Commercial chum catches were recorded as late as October 17, 1983.

2.2.6.1 Upper Kluane River Spawning Ground Surveys

Twenty-eight discrete spawning sites were identified, and 5,378 spawners were counted, in the upper Kluane River during an aerial survey conducted on October 14, 1982. During ground surveys of several of the spawning areas in 1982 and 1983, counts of spawners totalled 558 and 8,578, respectively (Table 7, Figures 14a and 14b). Ground surveys of spawning areas were limited by several factors, including the following:

Plate 7: This side channel on the Kluane River originates from upwelling groundwater. spawning occurred downstream in the upper portion of the photograph.

Table 7 Ground surveys of chum spawning areas located in the upper Kluane River

	AERIAL SURVEY* October 14, 1982		GROUND SURVEY October 22-26, 1982		GROUND SURVEY October 18-21, 1983		1983 SPAG.TAGS	
STATION NUMBER	LIVE	DEAD	LIVE	DEAD	LIVE	DEAD	REC./	OBS.
1	15	1	N.S.	N.S.	N.S.	N.S.		
2	38	10	N.S.	N.S.	N.S.	N.S.		
3	6	0	N.S.	N.S.	N.S.	N.S.		
4	29	0	10	1	0	0		
5	38	1			0	0		
6	17	0	N.S.	N.S.	N.S.	N.S.		
7	0	2	N.S.	N.S.	N.S.	N.S.		
8	209	6	N.S.	N.S.	N.S.	N.S.		
9	14	0	N.S.	N.S.	N.S.	N.S.		
10	1	0	75	12	0	0		
11	97	16			N.S.	N.S.		
12	458	25	300	113	N.S.	N.S.		
13	15	3			870	302	7	
14	45	7						
15	17	0						
16	4	0	N.S.	N.S.				
17	528	59	N.S.	N.S.	740**	50	3	
18	8	1	N.S.	N.S.				
19	31	1	N.S.	N.S.	0	410	24	3
20	124	7	N.S.	N.S.	4050**			
21	311	29	22	25				
22	105	16						
23	79	1						
24	2596	104	N.S.	N.S.	2156	Not Counted	6	4
25	15	6	N.S.	N.S.				
26	1	0	N.S.	N.S.	N.S.	N.S.		
27	180	6	N.S.	N.S.	N.S.	N.S.		
28	91	5	N.S.	N.S.	N.S.	N.S.		
SUB TOTAL	5072	306	407	151	7816**	762	40	7
TOTAL	5378		558		8578			

* Foothills Pipeline & D.F.O.

** Minimum count - most fish spawned out

N.S. Not Surveyed - due to ice conditions

Blank Spaces indicate total number found in combined area surveyed

REC- # of Spaghetti tags recovered

OBS- # of Spaghetti tags observed

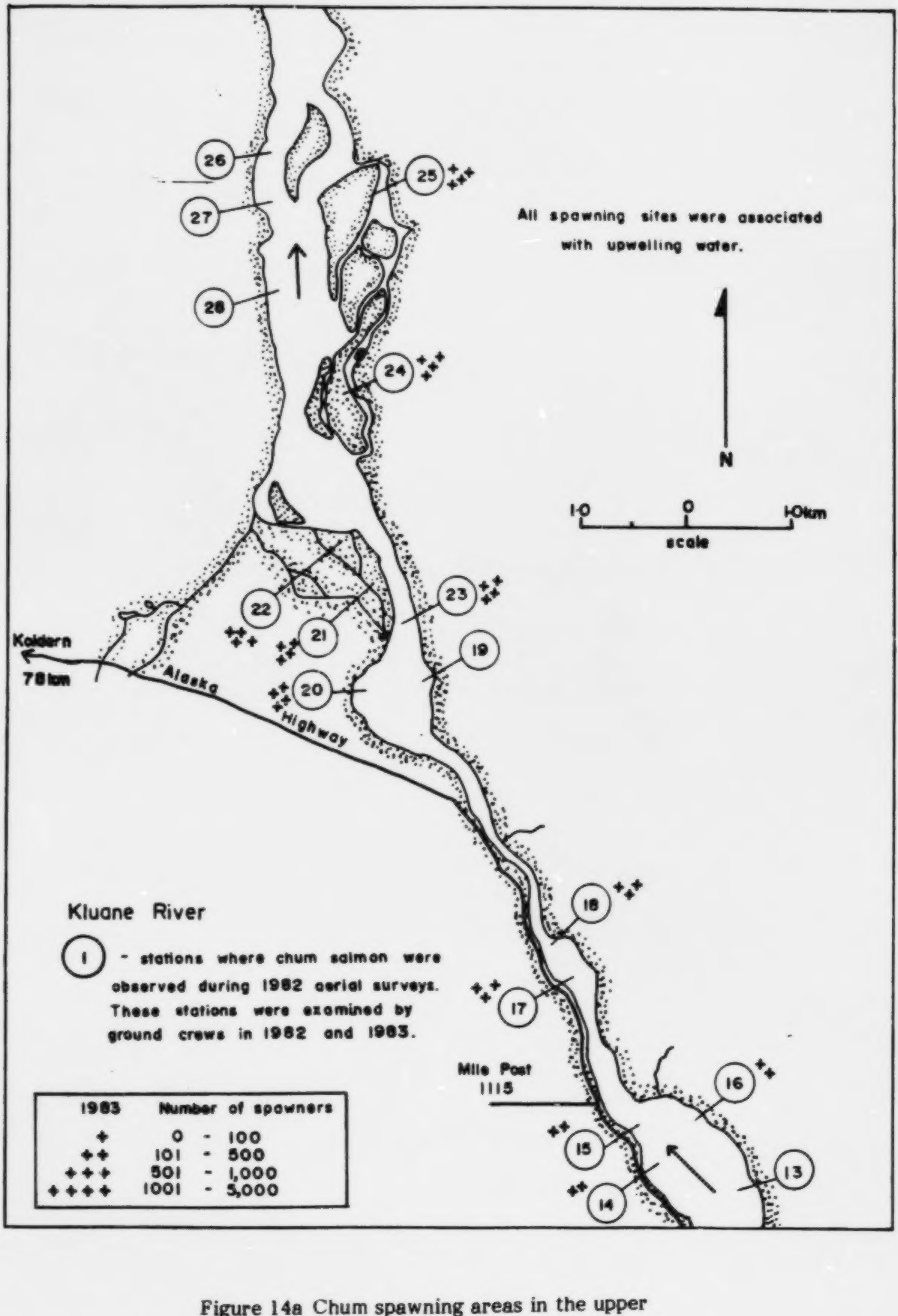
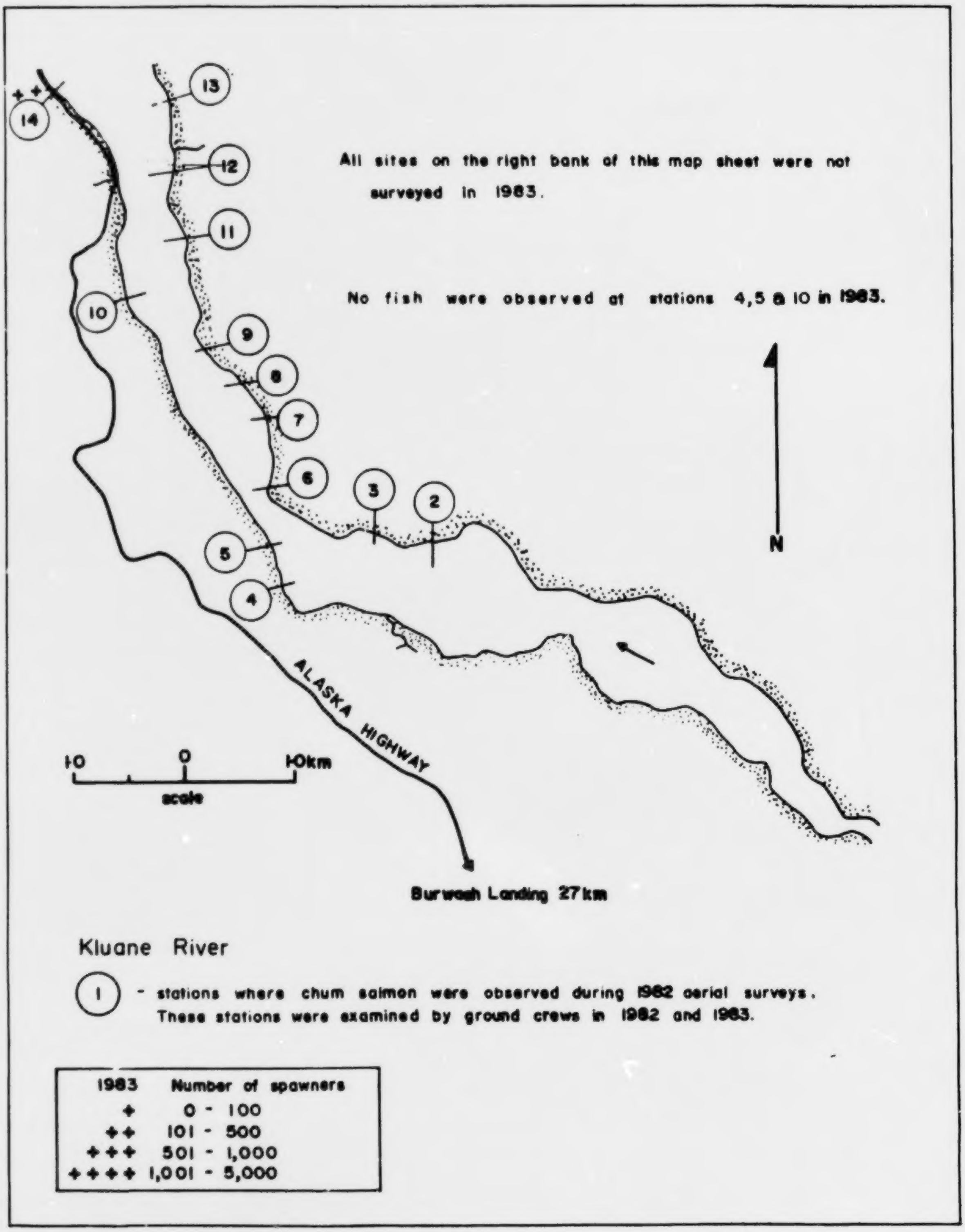

26
27
28
25
24
23
22
21
20
19
18
17
16
15
14
13
All spawning sites were associated with upwelling water.
N
1·0
0
1·0km
scale
Koidern
78km
Alaska Highway
Mile Post 1115
Kluane River
1 - stations where chum salmon were observed during 1982 aerial surveys. These stations were examined by ground crews in 1982 and 1983.
1983 Number of spawners
+ 0 - 100
++ 101 - 500
+++ 501 - 1,000
++++ 1001 - 5,000

Figure 14a Chum spawning areas in the upper Kluane River


14
13
12
11
10
9
8
7
6
5
4
3
2
N
ALASKA HIGHWAY
1·0
0
1·0km
scale
Burwash Landing 27 km
1983 Number of spawners
+ 0 - 100
++ 101 - 500
+++ 501 - 1,000
++++ 1,001 - 5,000

All sites on the right bank of this map sheet were not surveyed in 1983.

No fish were observed at stations 4,5 & 10 in 1983.

Kluane River

(1) - stations where chum salmon were observed during 1982 aerial surveys. These stations were examined by ground crews in 1982 and 1983.

Figure 14b Chum spawning areas in the lower Kluane River

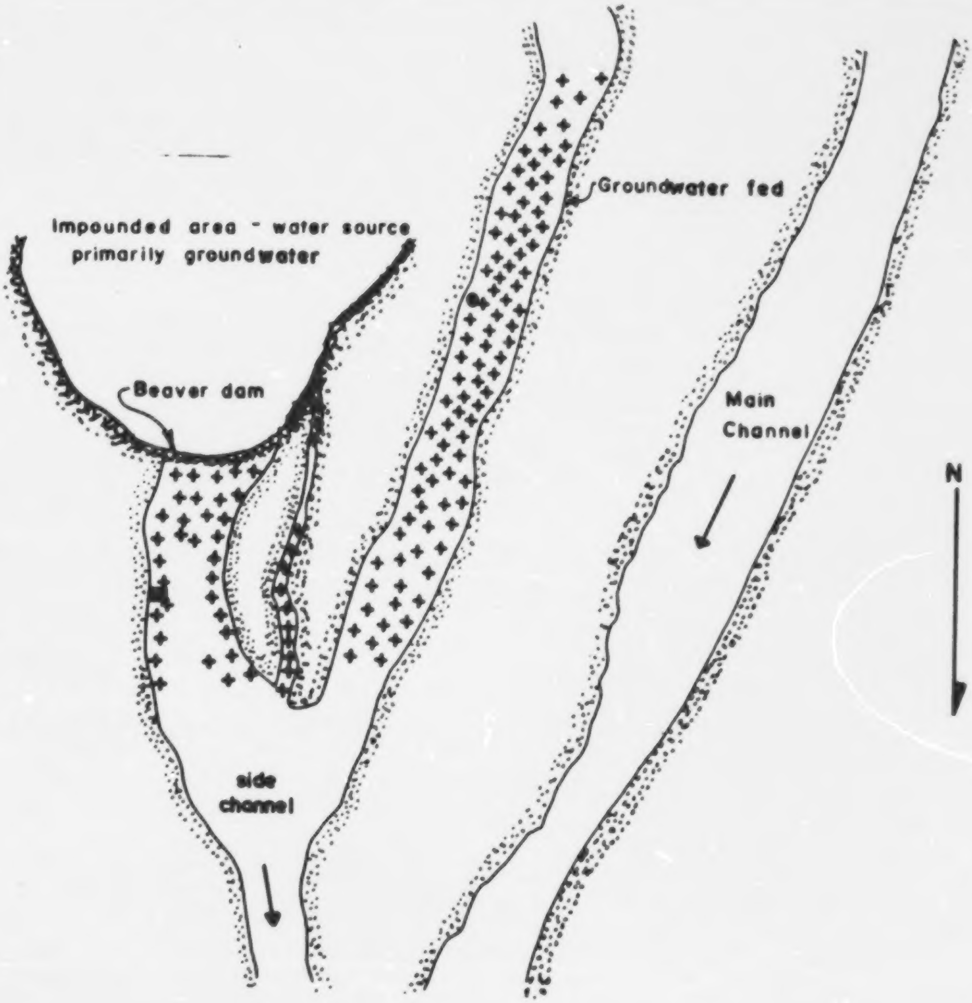
- the Kluane River was running ice during the 1982 ground survey;
- time constraints precluded a complete ground survey in 1983.

All chum spawning was associated with upwelling groundwater and the highest spawning concentrations were observed in the parts of the upwelling water areas that had the highest intragravel temperatures. A number of spawning areas were used extensively in both years (Plate 8). In the area of two adjacent spawning areas, identified as stations 24 and 25 (Figure 15), the numbers of chum salmon were 2,721 in 1982 and 2,156 in 1983 (Table 7), which were the highest local concentrations recorded during the study. Spawning occurred in two principal areas: below a beaver dam and in an adjacent side channel area. The water flow in the area near the beaver dam originated entirely from upwelling water, and in the adjacent side channel, although it was connected to the main river channel, an estimated 90% of its flow originated from upwelling water. Chum salmon were more concentrated in this side channel area where an intragravel temperature of 7°C was observed. Small craters in the substrate created by upwelling water were evident in both areas (Plate 9). The gravel composition in both areas had excellent spawning capabilities.

Extensive chum spawning was also observed in 1983 in the area of stations 20, 21 and 23, where 4,460 spawners were counted (Figure 16). Spawner counts were substantially lower in 1982, when aerial and ground counts of 672 and 47 chum, respectively, were recorded. Spawning in this area was not as concentrated as at stations 24 and 25, and many marginal habitat areas were utilized; however, over-crowding appeared to be a factor affecting spawning distribution in this area. Groundwater intrusion was predominant throughout this area, and, similarly to stations 24 and 25, a spawner preference for higher intragravel temperatures was evident.

A total count of 1,107 chum was observed at stations 13 and 16 in 1983. These areas were not extensively used in 1982 (91 chum). The most obvious source of upwelling water occurred at station 16 (Figure 17). Spawning was more prevalent in this area than in the other sloughs, where marginal habitat areas were utilized. Intragravel temperatures were constant at these stations, however, surface water temperatures varied.

Plate 8: A large concentration of spawning chum on the Kluane River (note splashing water). Peak spawning occurred during mid October.


Impounded area - water source primarily groundwater
Beaver dam
Groundwater fed
Main Channel
side channel
N

Kluane River, Station 24 & 25

Approximately 2,200 chum salmon were observed at these stations.

✚ - correspond to density and distribution of spawning chum.

Water temperature ● 7° C intragravel

4° C gravel surface

■ 6° C intragravel

5° C gravel surface

Not drawn to scale

Figure 15 Chum spawning at stations 24 and 25 in the upper Kluane River near mile post 1120 along the Alaska Highway

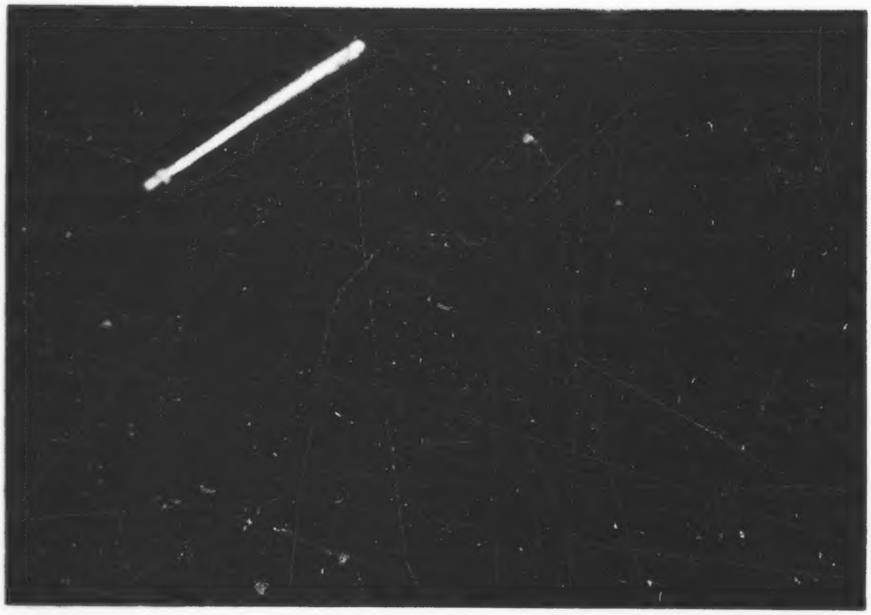


Plate 9: Craters created by upwelling groundwater at station 25, Kluane River. High intragravel temperatures occurred in these upwelling areas. The thermometer case (16 cm in length) indicates the relative size of craters.

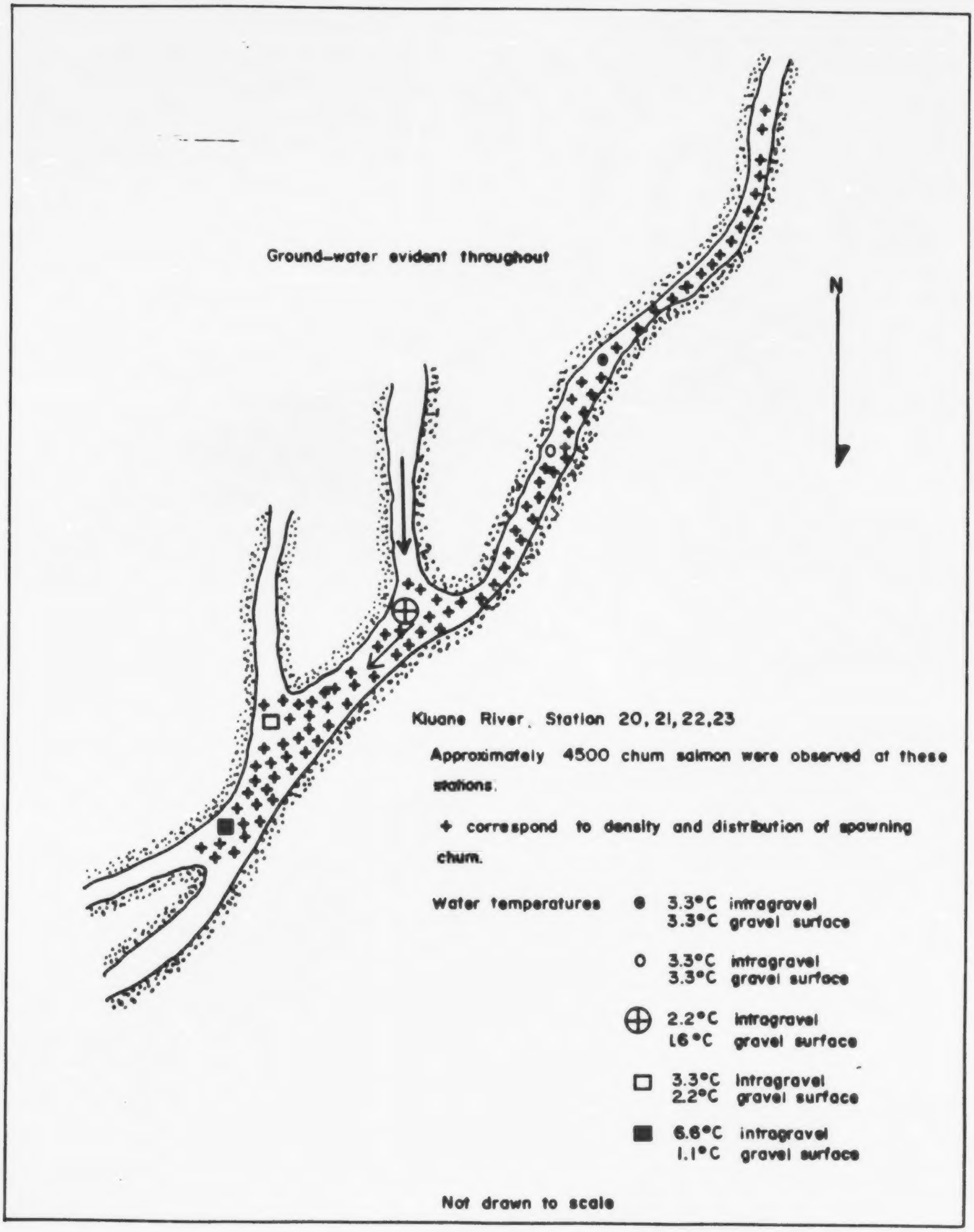

Ground-water evident throughout
N
Kluane River, Station 20, 21, 22, 23
Approximately 4500 chum salmon were observed at these stations.
✚ correspond to density and distribution of spawning chum.
Water temperatures
● 3.3°C intragravel
3.3°C gravel surface
○ 3.3°C intragravel
3.3°C gravel surface
⊕ 2.2°C intragravel
1.6°C gravel surface
□ 3.3°C intragravel
2.2°C gravel surface
■ 6.6°C intragravel
1.1°C gravel surface
Not drawn to scale

Figure 16 Chum spawning at stations 20 to 23 in the upper Kluane River adjacent to mile post 1110 along the Alaska Highway

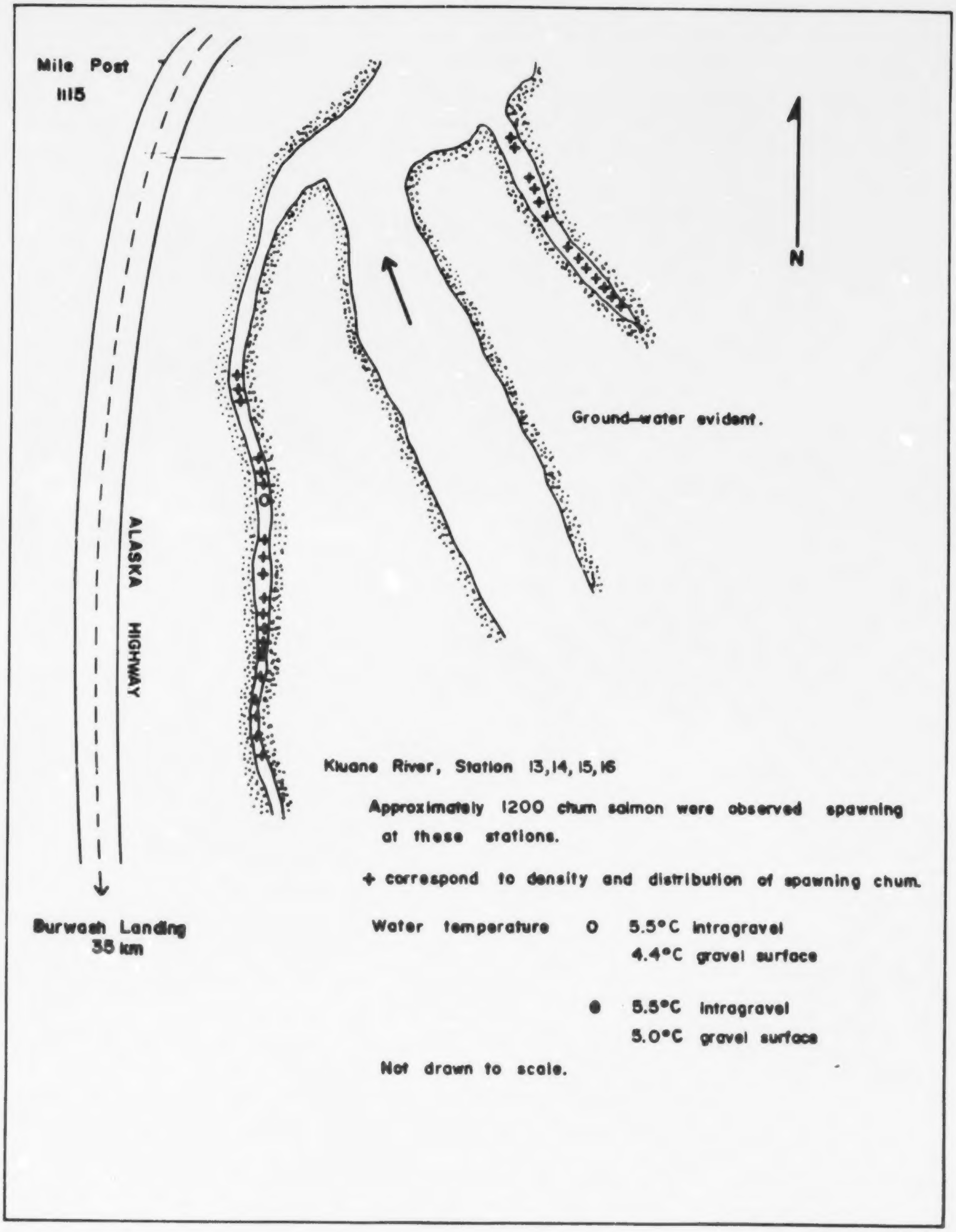

Mile Post
1115
N
Ground-water evident.
ALASKA HIGHWAY
Burwash Landing
35 km
Kluane River, Station 13, 14, 15, 16
Approximately 1200 chum salmon were observed spawning at these stations.
+ correspond to density and distribution of spawning chum.
Water temperature ○ 5.5°C intragravel
4.4°C gravel surface
● 5.5°C intragravel
5.0°C gravel surface
Not drawn to scale.

Figure 17 Chum spawning at stations 13 to 16 in the upper Klaune River adjacent to mile post 1115 along the Alaska Highway

At stations 17 and 18, the total 1983 count was 790 chum (Table 7), which was similar to the 1982 count of 596 chum. Spawning occurred in side channel areas, primarily along the shoreline, with the highest chum concentration occurring in a side channel having a higher intragravel temperature (Figure 18).

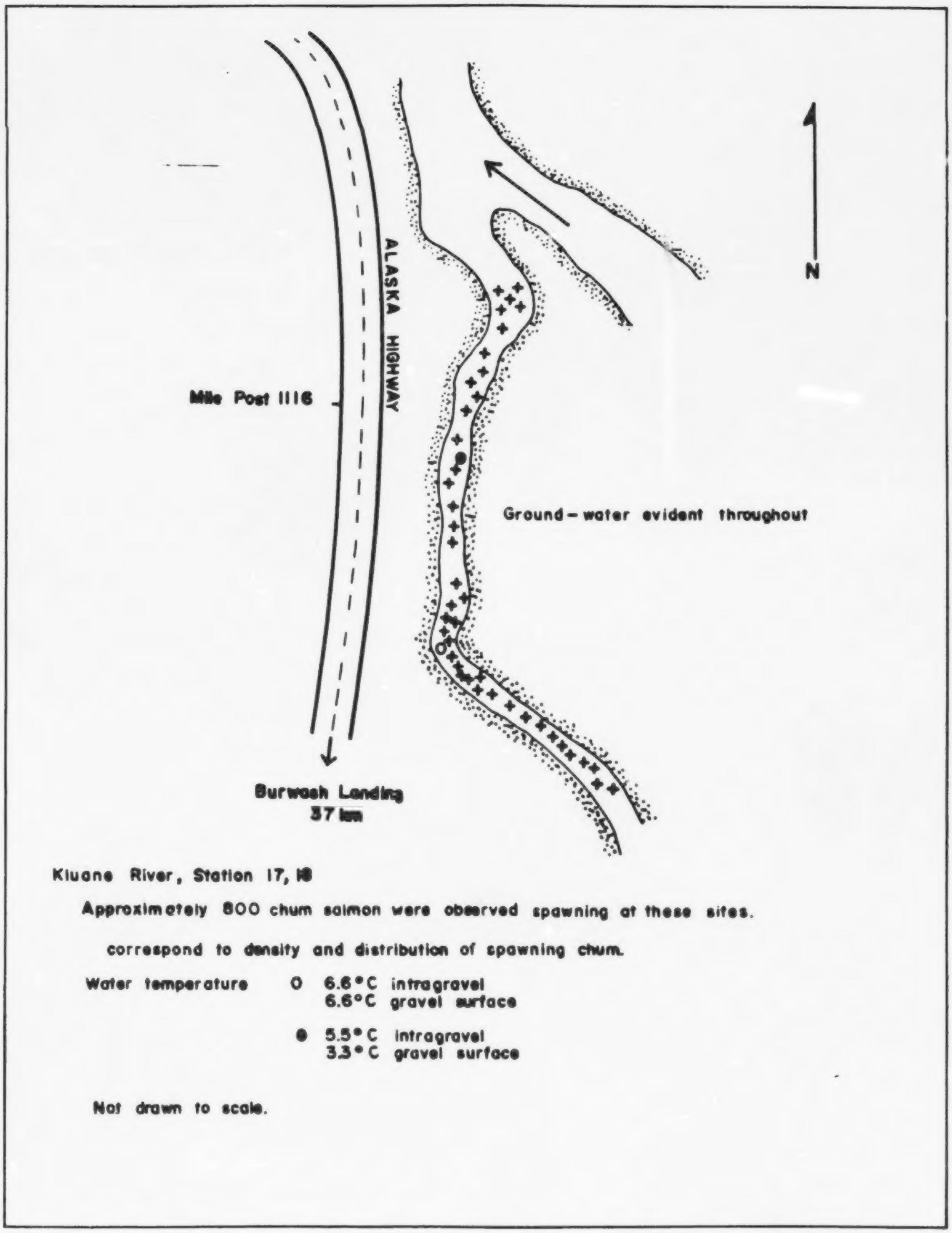
The spawning areas identified as stations 13 and 16 were located in sloughs. Spawner counts were 1,107 in 1983, and were substantially lower (91) in 1982. Groundwater inflow, which was prevalent at both sites, was particularly evident at station 16. Intragravel temperatures were constant at these stations, in contrast to varying surface water temperatures. Spawning was more prevalent in the station 13-16 areas than in other sloughs, where marginal habitat areas were utilized.

A total of 40 spaghetti tags were recovered and seven other tags were observed in the spawning locations surveyed in the upper Kluane River in 1983 (Appendix 3).

2.2.6.2 Mainstem Yukon Spawning Ground Surveys

A 110 km section of the mainstem Yukon River in the Minto area (Figures 12 and 13) was surveyed in 1982 and 1983. The 1982 survey involved a general search of all potential mainstem spawning areas, whereas the 1983 survey was directed at open water areas identified during the aerial survey conducted on March 8, 1983 (section 2.2.5), when 42 open water sites were identified. Thirty-one of these sites were surveyed, and 13 (42%) were found to support spawning chum. The surveys did not include investigation of the relationship between intragravel temperatures and habitat preference.

Totals of 1,100 and 7,560 spawning chum were observed during ground searches conducted in 1982 and 1983, respectively (Table 8). The greatest concentration of chum was observed at km 416 (Figure 19), where 800 and 3,618 chum were observed in 1982 and 1983, respectively (Table 8). This was the only mainstem spawning area identified in 1983 that was not associated with an obvious winter open water site. Groundwater discharge evidently was present, but it may


N
ALASKA HIGHWAY
Mile Post 1116
Ground-water evident throughout
Burwash Landing
37 km

Kluane River, Station 17, 18

Approximately 800 chum salmon were observed spawning at these sites.

correspond to density and distribution of spawning chum.

Water temperature ○ 6.6°C intragravel
6.6°C gravel surface

● 5.5°C intragravel
3.3°C gravel surface

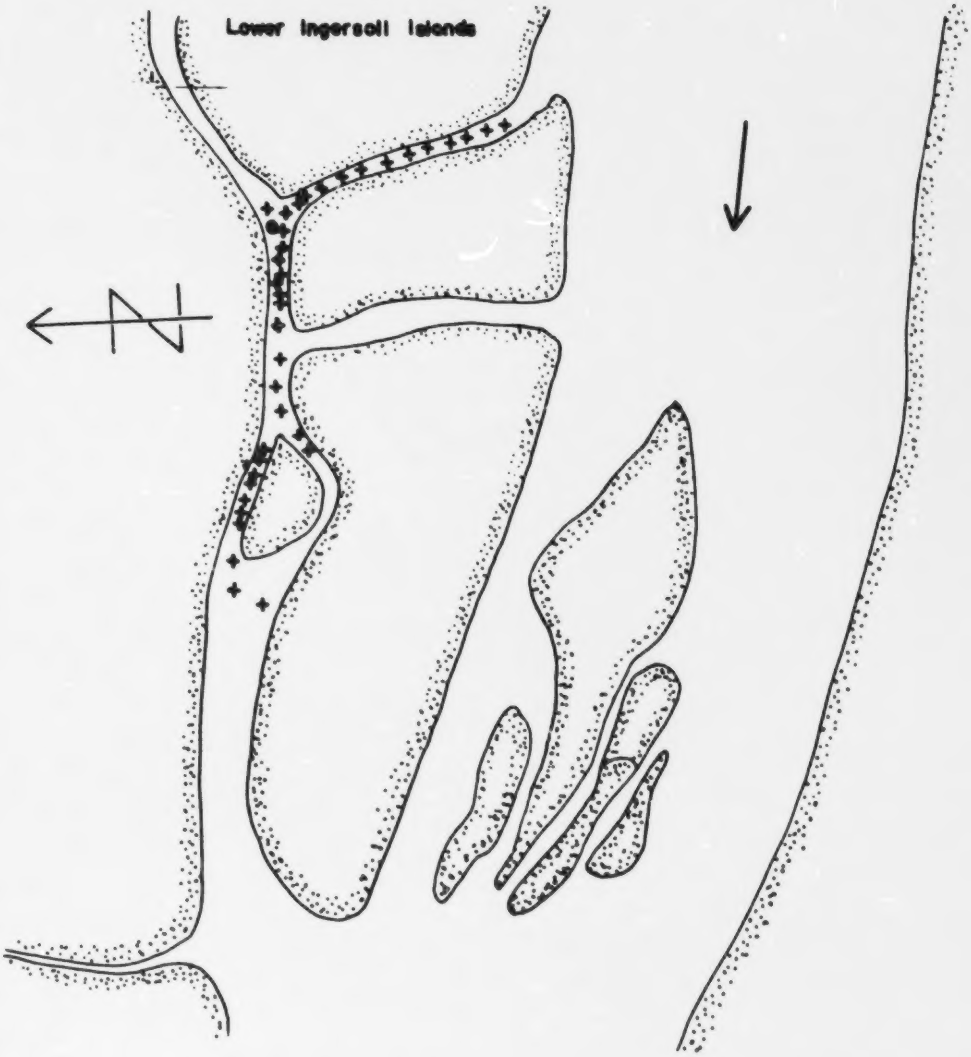
Not drawn to scale.

Figure 18 Chum spawning at stations 17 and 18 in the upper Kluane River adjacent to mile post 1116 along the Alaska Highway

TABLE 8. Ground surveys of chum spawning areas in the Yukon River located on the 1:250,000 Carmacks mapsheet (115-I).

River Dis From low Tag Site KM	NUMBER OF OPEN WATER AREAS*	1975**	1982***	1983*** Oct. 9-15	1983*** Oct. 22-25	1983 SPAG.TAGS REC./	OBS.
368-372	3	0	0	N.S.	500****	1	1
372-376	1	0	20	N.S.	0		
376-380	0	0	16	N.S.	0		
380-384	2	0	0	N.S.	3****		
384-388	0	0	0	N.S.	0		
388-392	0	0	0	N.S.	0		
392-396	2	0	0	N.S.	0		
396-400	1	25	0	N.S.	0		
400-404	1		0	N.S.	0		
404-408	3	4	0	N.S.	21****	1	
408-412	3	290	0	N.S.	640****		1
412-416	2	560	0	N.S.	0		
416-420	1	1205	800	2168	1450****	3	3
420-424	1		0	60	N.S.		
424-428	1	2	0	N.S.	0	2	
428-432	2	0	40	196	520***		
432-436	2	1505	200	1446	N.S.	2	2
436-440	1	92	24	430	N.S.	1	
440-444	0	5	0	0	N.S.		
444-448	1	64	0	2	N.S.		
448-452	3	234	0	20	N.S.		
452-456	3	213	0	0	N.S.		
456-460	0	0	0	0	N.S.		
460-464	1	1750	0	2	N.S		
464-468	1	0	0	0	N.S.		
468-472	2	22	0	N.S.	N.S.		
472-476	3	763	0	0	N.S.		
476-480	1	8	0	102	N.S.		
480-484	1	461	0	0	N.S.		
TOTALS		7203	1100	4426	3134	10	7
TOTAL 1983 COUNT					7560		

*	Refer to Sections 2.1.9 and 2.2.6
**	Maximum counts from Walker (1976)
***	Counts included live and dead chum
****	Survey was conducted after peak spawning in an area that had not previously been surveyed in the October 9, 1983 ground survey
N.S.	Indicates the area was not surveyed
REC.	# of Spaghetti tags recovered
OBS.	# of Spaghetti tags observed



Yukon River, Site 1, Km 416

Approximately 4,000 chum were observed spawning at this site.

+ - correspond to density and distribution of spawning chum.

● - Water temperature 2.2° C intragravel
1.6° C gravel surface

Not drawn to scale.

Figure 19 Chum spawning area (km 416), mainstem Yukon, located 24 km downstream of Minto

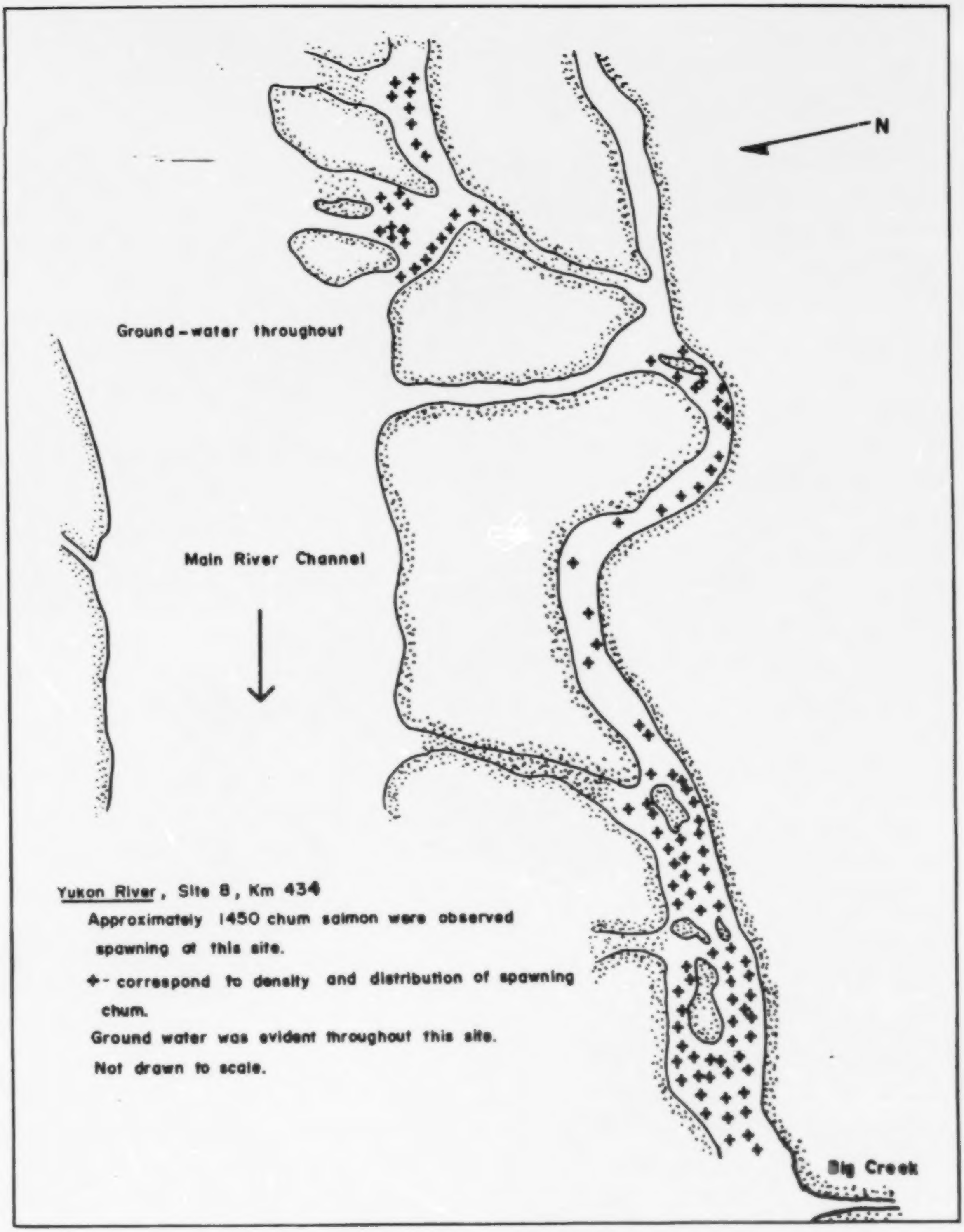
not have been indicated by an open water area in winter because it would have been mixed with a large volume of river water.

At km 434, 1,446 chum were observed in 1983 (Figure 20), which is substantially higher than the 1982 count of 200 chum. Spawning occurred primarily in riffle areas in 1982, however, less suitable habitat was used in 1983, suggesting that the increased abundance of chum in 1983 displaced fish to less suitable spawning areas. Groundwater intrusion was evident in this area.

Spawning areas of secondary importance, in terms of spawner counts, were located at km 369 and km 429. Five hundred chum were observed at km 369 (Figure 21), where spawning was limited to the centre of the channel where upwelling water was evident. At km 429 (Figure 22), located in a slough area where upwelling water was prevalent, 520 chum were observed, with redds being concentrated mainly near the source of upwelling water at the upper end of the slough. Other redds were located in small side channels farther downstream.

Many of the spawning areas surveyed in both 1982 and 1983 were investigated by a 1975 study (Walker, 1976). Because 1983 represented a cycle year for the 1975 and 1979 chum returns (predominant four-year cycle), it was expected that the same spawning areas would be used in 1983, but this was not the case. The most important spawning area identified in 1975 (1,750 chum observed in a slough between km 460 and 464) was not used in 1982 and one spawning pair was observed there in 1983. The abandonment of the most important spawning area was perhaps related to an environmental change. Field personnel observed ice cover in the upper slough in the winter and a 1-2 cm covering of aquatic algae on the spawning substrate in the fall. These observations could indicate the flow of upwelling water had diminished.

It was apparent from the spawning ground surveys conducted in 1982 and 1983 that chum salmon preferred spawning areas with upwelling groundwater. Kogl (1965) speculated that a direct relationship exists between the number of spawning chum and the amount of spring-fed habitat available. The preference for upwelling groundwater could have an adaptive advantage for the species, in that the warmer


N
Ground-water throughout
Main River Channel
Big Creek

Yukon River, Site 8, Km 434

Approximately 1450 chum salmon were observed spawning at this site.

✚ - correspond to density and distribution of spawning chum.

Ground water was evident throughout this site.

Not drawn to scale.

Figure 20 Chum spawning area (km 434), mainstem Yukon, located 6 km downstream of Minto

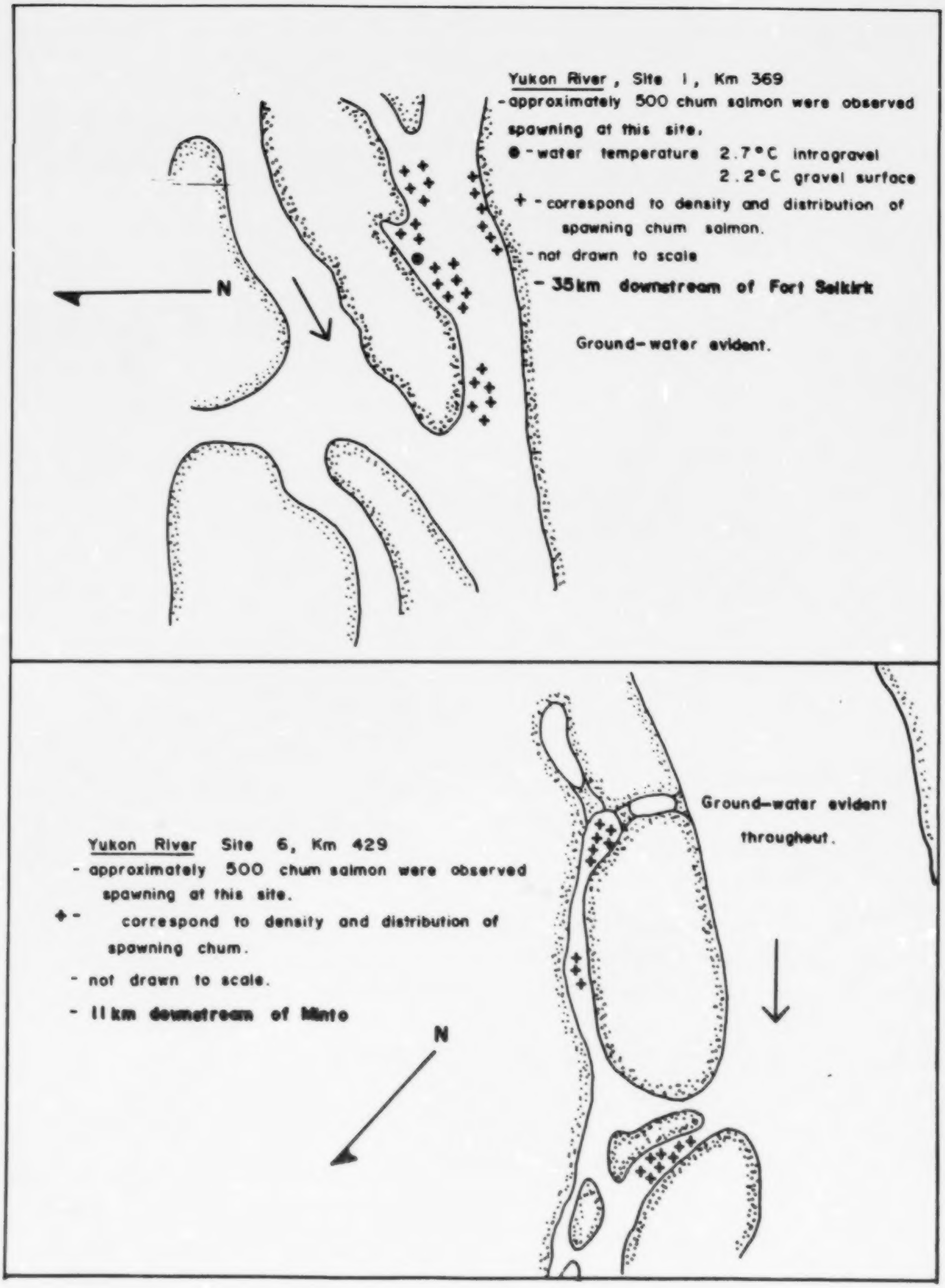

Yukon River, Site 1, Km 369
- approximately 500 chum salmon were observed spawning at this site.
● - water temperature 2.7°C intragravel
2.2°C gravel surface
+ - correspond to density and distribution of spawning chum salmon.
- not drawn to scale
- 35km downstream of Fort Selkirk
Ground-water evident.
N
Yukon River Site 6, Km 429
- approximately 500 chum salmon were observed spawning at this site.
+ - correspond to density and distribution of spawning chum.
- not drawn to scale.
- 11km downstream of Minto
Ground-water evident throughout.
N

Figure 21 Chum spawning areas: km 429 and km 369, mainstem Yukon

temperatures associated with upwelling water would prevent redds from freezing, thus ensuring higher survival of overwintering eggs. Upwelling groundwater may also be important to other fish species. Field personnel observed large chinook redds and juvenile whitefish and sculpins in these areas.

In summary, spawning ground counts were higher in both the Kluane and mainstem Yukon areas in 1983 (16,138) than in 1982 (6,478). This was also apparent in the increase in the number of spaghetti tags applied (1,082 in 1982 and 3,176 in 1983) and the increased catch of chum salmon in the commercial fishery. A total of ten spaghetti tags were recovered (seven other tags were observed) in the mainstem Yukon River spawning areas in 1983 (Appendix 4).

2.2.7 Migration Rates and Timing

Average chum migration rates were 30.5 (n = 116) and 31.6 (n = 444) $km.day^{-1}$ in 1982 and 1983, respectively. The average migration rate above the Stewart River in 1983 was 35.7 $km.day^{-1}$ (n = 24).

The 1982 chum run occurred approximately one week earlier than in the previous two years. The first chum was tagged on August 9; the last one, on October 4. Peak migration occurred between September 21 and September 27 (Figure 22), and an earlier migration peak was evident September 7-13. In 1983, the first and last chum were tagged on July 18 and October 2, respectively, and peak migration occurred during the week of September 20 to 26 (Figure 23).

There was little variation in average migration rates between 1982 and 1983. A similar migration rate of 28.4 $km.day^{-1}$ was determined in a chum tag-recovery program conducted in 1974 (Brock, 1976). Migration timing through the Dawson area varies from year to year, probably because of several effects, including annual run strength and annual discharge levels.

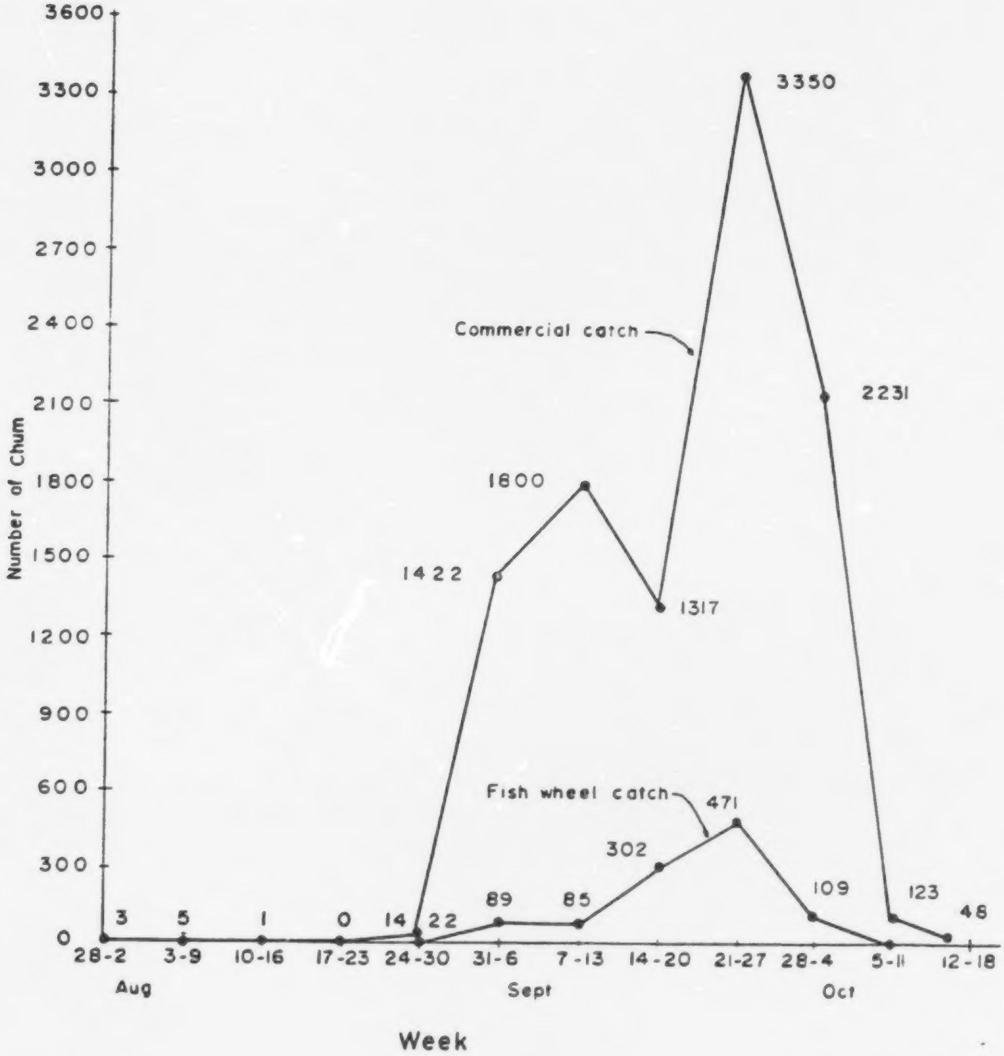


Figure 22 Fishwheel and commercial (Dawson area) chum catches, 1982

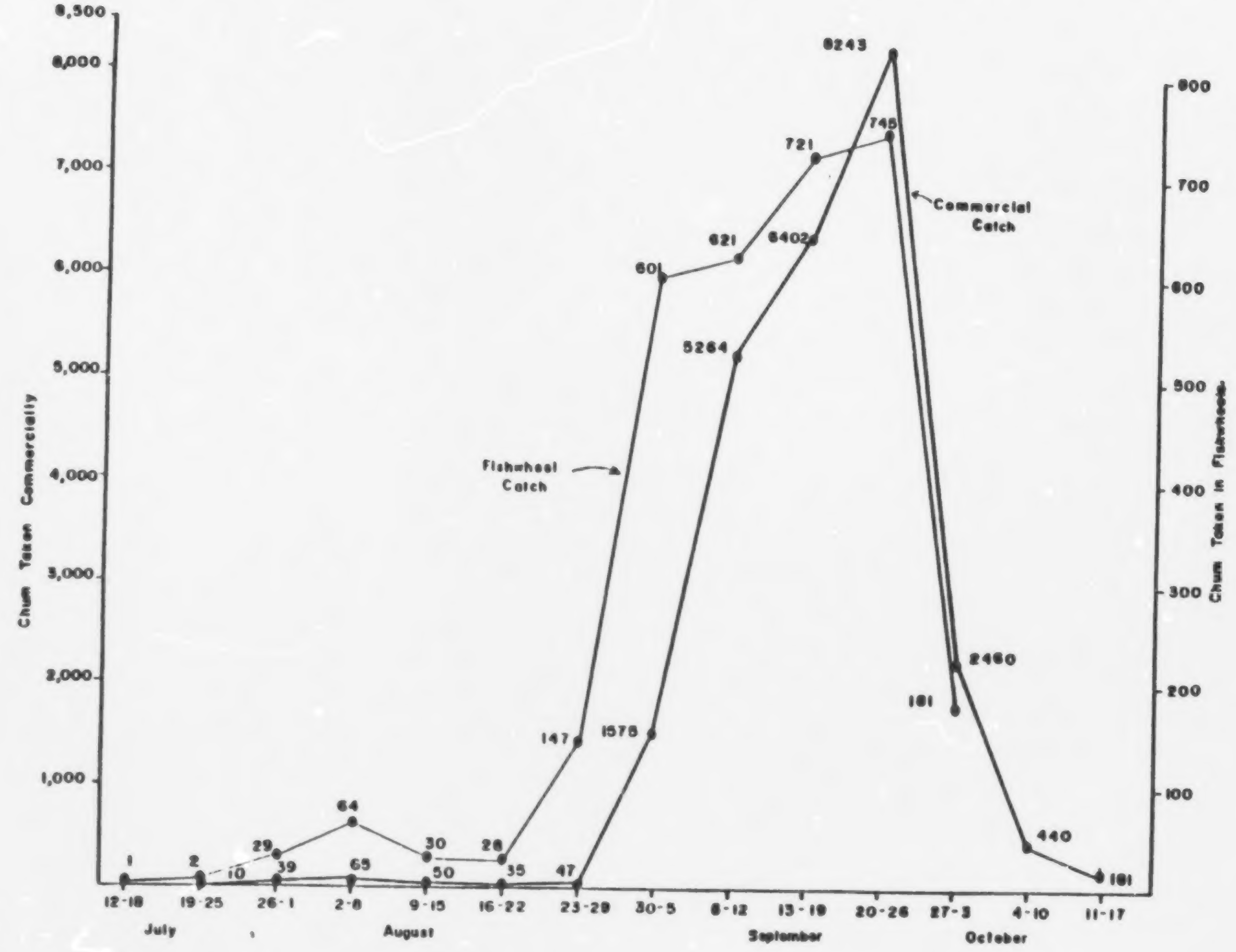


Figure 23 Migration timing and relative abundance of chum salmon as determined by fishwheel and commercial catches, 1983

3.0 CHUM RADIO-TAGGING PROGRAM 1982

3.1 Materials and Methods

3.1.1 Capture Techniques

Chum salmon were live-captured by small mesh gillnets and by fishwheels located 7, 12, and 135 km above the international boundary (Figure 1). The fishwheels at km 7 and km 12 were constructed and operated by DFO staff (described in section 2.1.1.1), while the fishwheel at km 135 was operated by a commercial fisherman. Chum salmon were scooped up by the fishwheel baskets and deposited into live-boxes (section 2.1.1.1), or in the case of the upper commercial fishwheel, into fish totes (1 m length x .5 m width x .5 m depth) filled with water. The gillnets, which measured 16 m (length) x 2.5 m (depth) with a 10.2 cm mesh size (stretched measure), were set in eddies located near the km 12 fishwheel.

3.1.2 Radio Telemetry Equipment

The radio telemetry equipment used in this study was manufactured by Wildlife Materials, Inc., Carbondale, Illinois. The radio transmitters used were individually identifiable and operated on frequencies in a 1,000 kilohertz band between 150.800 and 151.800 megahertz. The separation between each frequency was approximately 20 kilohertz. Each transmitter was a self-contained, hermetically sealed unit with an outer shell consisting of dental acrylic and an external whip antenna 20 mm in length. All transmitters were two-stage, miniature units which emitted pulsing signals at rates of 45-50, 60-75, 96-120 or 150-200 pulses per minute. These four pulse rates were used in conjunction with 50 frequencies, so that a total capacity of 200 individually identifiable transmitters was available. Transmitter dimensions, weight, and life expectancy were variable, depending on the pulse rate, pulse width, and the size of the lithium battery used. Transmitter dimensions were 45-55 mm (length) x 20-23 mm (width) x 20-22 mm (maximum diameter) (Figure 24), with a dry weight between 16 and 26 grams. The transmitters had a life expectancy of 50-90 days and were activated by the removal of a small external magnet which operated as the on/off switch.

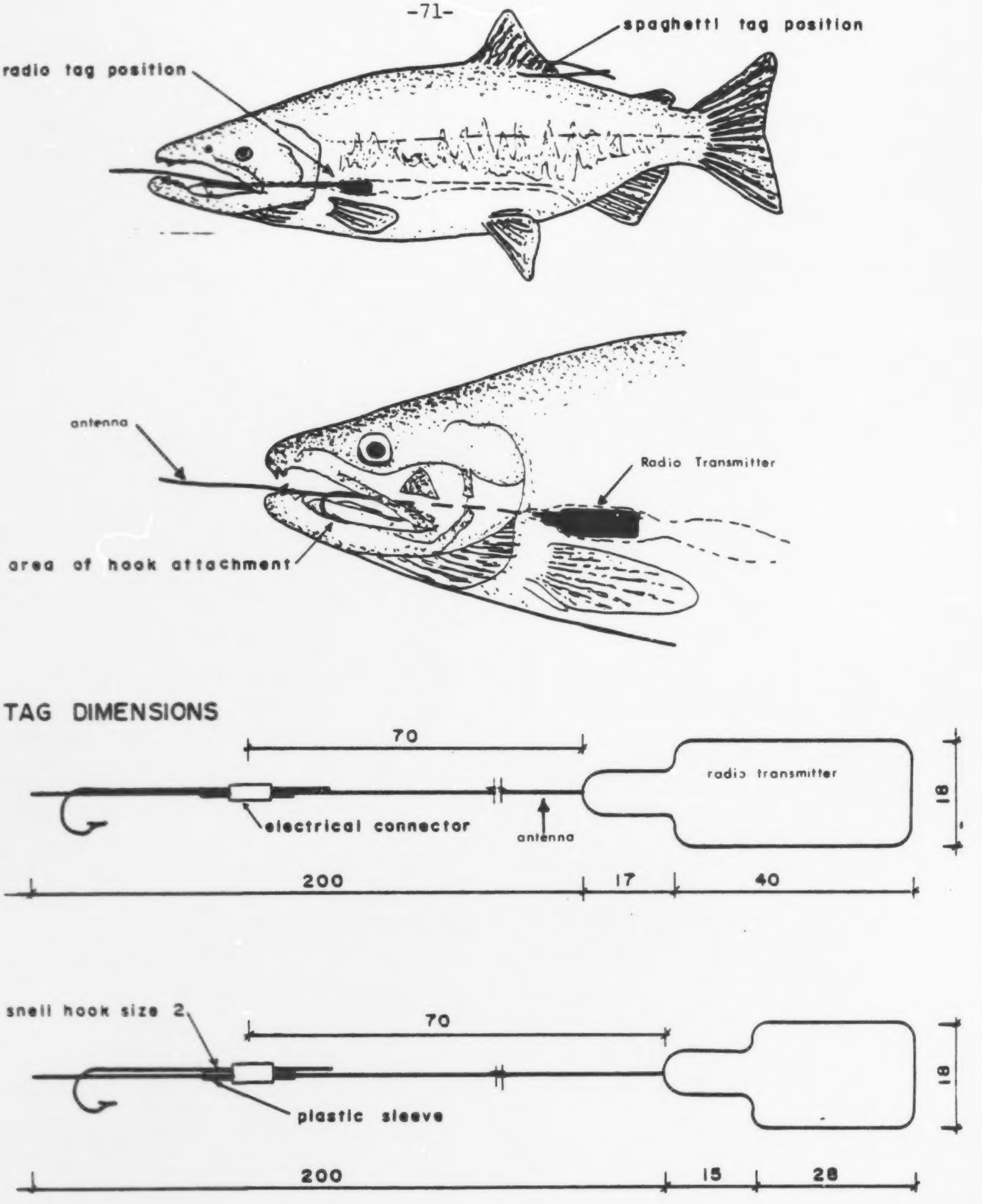

spaghetti tag position
radio tag position
antenna
Radio Transmitter
area of hook attachment
TAG DIMENSIONS
70
radio transmitter
electrical connector
antenna
18
200
17
40
snell hook size 2
70
plastic sleeve
18
200
15
28

Figure 24 Transmitter placement in anterior stomach. The area of hook attachment is shown in middle figure. Actual transmitter dimensions are shown in bottom figures. All measurements are in millimeters

Transmitter range varied with the depth of the fish in the water, and the transmitter orientation to receiving antennae. Signal range averaged approximately 0.8 km on the ground and 1.6 km from the air.

Two types of radio receivers were used. Both operated on a 1,000 - 1,200 kilohertz band of reception which complemented the frequency range of the transmitters. One type was a programmable Falcon Five receiver (1,000 kilohertz range) used with an APS-164 lid-mounted scanner. This unit was equipped wth a memory capacity of 64 individual channels and variable scan rates from 5 to 40 seconds/channel. A rapid activation-deactivation system permitted selecting and scanning of a number of discrete frequencies at any given time. The second type of receiver was a TRX-24 receiver, which operated over a 1,200 kilohertz range. Any frequency within this range could be manually selected. Each channel covered approximately 25 kilohertz with a 5 kilohertz overlap between channels.

Two types of antenna arrays were used, both involving matching pairs of omni-directional citizens band (CB) whip antennae. A pair of self-grounding 1/2 wavelength antenna (one meter in length) was mounted with brackets and hose clamps to the front wing struts of the aircraft (facing downward). A full wavelength pair of antenna (two meters in length) was vertically mounted and grounded to a telescopic bar that spanned between the metal steps of the aircraft (Figure 25). Each full wavelength antenna was located a distance of 1/2 wavelength from the fuselage of the aircraft. Each antenna was linked by RG 58U co-axial cable in a co-phase hookup to an external connector located on the underside of the fuselage. Independent antenna leads were available inside the aircraft.

Three element Yagi antennae were used for ground tracking. These were either hand held or attached to a boom (three meters in length) fastened to the boat.

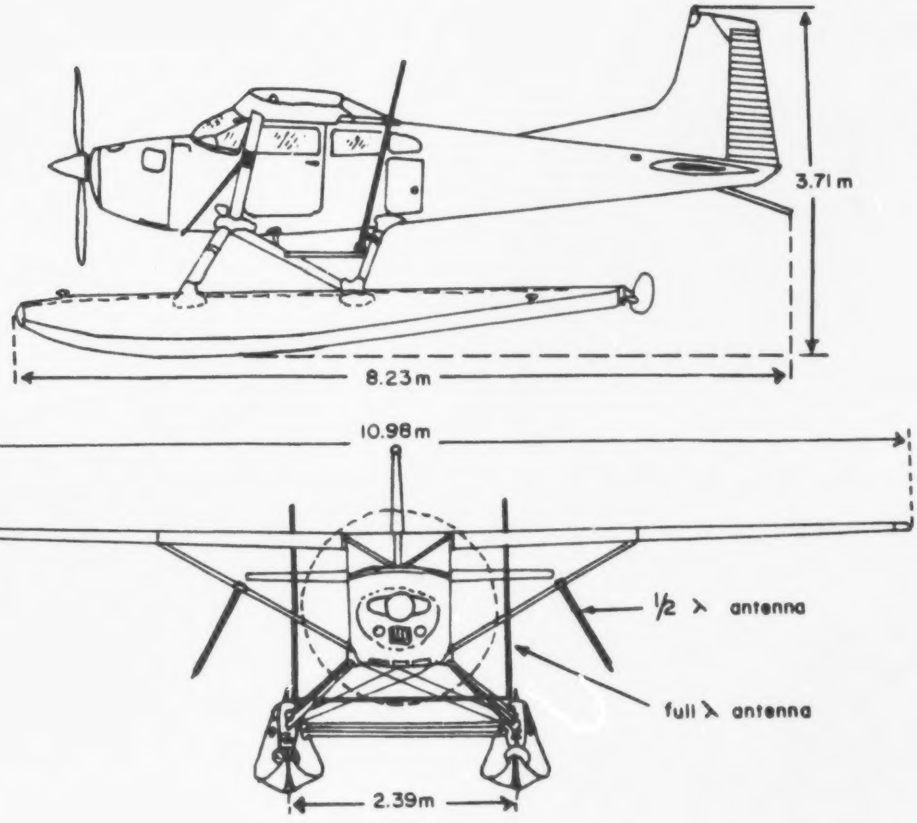

3.71 m
8.23 m
10.98 m
1/2 λ antenna
full λ antenna
2.39m

Figure 25 Cessna 185 floatplane with 1/2 wavelength antennae (1 meter) attached to front wing struts and full wavelength antenna (2 meters) positioned behind wings.

3.1.3 Transmitter Implantation

Transmitter implantation took place in fishwheel live-boxes at the lower fishwheels and in fish totes at the commercial fishwheel. During the early part of the program, the transmitters (tags) were coated with bee's wax (an inert substance) to reduce the abrasive nature of the acrylic coating. This was later discontinued because the bee's wax increased tag dimensions. Glycerine was liberally applied to each tag as a lubricant. Tag implantation required two people, one to hold the fish by the caudal peduncle with one hand and cradled its body with the other, while keeping its head submerged in the water; and the other to insert the radio transmitter, by using a middle finger to push in the tag while the adjacent two fingers traced alongside the lower jaw. The tag was pushed until it seated in the lower esophagus or anterior to the stomach (Figure 24). In cases where the tag was not inserted a sufficient distance to clear the esophageal sphincter, a pencil was used to push the tag in farther. The whip antenna protruded from the fish's mouth. The fish were released immediately after tag insertion which took 15 seconds to 1 minute to complete. Anesthetics were not used in an attempt to reduce possible trauma to the fish. The transmitter size used was determined by the size of the fish, so that small fish, for example, were tagged with the smaller sized transmitters.

Fishhooks were used after September 19 to fix the tags and prevent them from slipping through the gut lining. A hook was attached to the antenna of the transmitter by an electrical connector and was insulated from the antenna with hollow plastic wire sheathing approximately 2.5 cm in length. The hook was embedded in the cartilaginous material of the lower jaw (Figure 24).

In an attempt to reduce the trauma that the fish experienced from the tagging process, water in the fish tote at the upriver tagging site (commercial fishwheel) was saturated with oxygen from a standard oxygen bottle. The tagged fish were held in the fish tote until they demonstrated "reduced trauma" prior to being released. Although this procedure was somewhat subjective, the fish usually became more sedentary and orientated themselves toward the source of oxygen. Maximum holding time with this procedure was approximately 10 to 15 minutes.

Transmitter placement was examined through necropsies to ensure that the transmitters were properly seated in the gut. Fish recaptured in the various fisheries were also examined to check the integrity of the gut lining.

3.1.4 Tracking Techniques

Tracking near the tagging site was conducted either by boat or on foot. Observers used manual and/or programmable receivers and directional Yagi antennae to determine the fish's initial movements and immediate response to tag implantation, and, most importantly, to determine possible migratory delay. It was assumed that undisturbed fish would exhibit continuous upstream migration; therefore, any post-tagging delay or eratic behaviour was expected to be tag induced.

Aerial tracking surveys were conducted daily with a Cessna 185 floatplane. Surveys were flown at airspeeds between 137 and 209 $km.h^{-1}$ at an altitude of approximately 305 metres above the river. Two observers were usually used during aerial surveys. Each observer had an independent scanner-receiver, antenna array, and headphone set. Distances from the respective tagging sites were marked on 1:250,000 scale maps in two kilometer increments. Kilometre "0" was the site of the lowest fishwheel (Figure 1). This fishwheel was positioned 7 km upstream of the international boundary. The location (to the nearest kilometre) of each fish observed and the time of the observation were recorded. A daily migration rate was calculated for each fish with the following formula:

$$\text{Daily migration rate} = \frac{\text{distance travelled between observation (km)}}{\text{number of hours elapsed (h)}}$$

The calculated migration rate was then used to predict the location of the fish during subsequent surveys.

During aerial surveys, observers scanned a maximum of five to nine frequencies at any time. Several factors limited the number of frequencies that could be scanned, including the speed of the aircraft, signal strength, and the amount of time required for a complete scanning sequence.

3.1.5 Biological Sampling

Biological sampling was conducted during tag implantation. Sex was determined by visual examination of body shape and/or secondary sex characteristics. Two scales were removed in the manner described previously in section 2.1.5. Fork length was determined to the nearest millimetre with a 1000 mm hypural stick. Because the collecting of biological information was of secondary importance to the main goals of rapid transmitter implantation and immediate release of the fish, scale samples were not always taken.

3.2 Results and Discussion

3.2.1 Transmitter Application

Between August 28 and October 7, 1982, 114 radio transmitters were applied (Appendix 5), of which 62 were applied between August 28 and September 18 to chum live-captured by fishwheels located 7 and 12 km above the international border (Figure 1); two were applied to chum live-captured by small mesh gillnet on August 28 and 29, and 50 transmitters were applied to chum live-captured between September 19 and October 7 by a commercial fishwheel located 5 km below Dawson City.

The techniques used during transmitter implantation were successful in reducing handling time. The fish were tagged (with their heads submerged in the water) and released within one minute. The typical post-tagging behaviour involved sounding (fish moving to bottom) and remaining there for a variable time period (which was not analyzed quantitatively). The use of compressed oxygen combined with a holding period of 10 to 15 minutes reduced or virtually eliminated the post-tagging delay period, and in many cases the fish resumed their upriver migration immediately upon release.

The fishhook technique of securing the transmitters was successful. All transmitters secured in this manner were still fixed when the fish were recaptured in various upriver fisheries.

3.2.2 Recaptures in Commercial, Subsistence and Domestic Fisheries

Twenty-eight of the 114 radio-tagged chum were recaptured in commercial, subsistence and domestic fisheries (Appendix 7). This represents an exploitation rate of 24%. Recaptures within the various fisheries were as follows:

- 20 recaptured by commercial gillnet
- 2 recaptured by subsistence gillnet
- 3 recaptured by domestic gillnet
- 2 recaptured by commercial fishwheel
- 1 gilled by fishwheel weir

28 Total

Recaptures were influenced by the location of the tagging sites relative to areas of commercial fishing pressure, which was greatest in the area between the lower tagging sites and Dawson City. Of the 63 radio-tagged chum released at the lower tagging sites, 23 were recaptured in this fishery, indicating an exploitation rate of 35%. This was somewhat higher than a rate of 26.2% determined from spaghetti tag returns, although the spaghetti-tagged sample size was small. Twenty-one of these radio tags were recaptured in the commercial fishery below Dawson City, one by a subsistence gillnet in a mainstem spawning area near Minto, and by a domestic gillnet near Eagle, Alaska, downstream of the tagging site.

Six of the 50 radio-tagged chum released from the upriver tagging site were recaptured, indicating an exploitation rate of 12%. Three of these were recaptured by commercial gear in the immediate area while the other three were recaptured in upriver areas. Two of the upriver recoveries were made in a domestic net at Stewart Island, and the third recovery was made in a commercial gillnet located near Coffee Creek (km 308). The latter fish was thought to be spawning near Coffee Creek.

3.2.3 Regurgitations and Mortalities

Eleven transmitter applications resulted in suspected or confirmed regurgitations. Most regurgitations occurred shortly after tagging near the tagging location. Although there was no definitive cause and effect relationship between transmitter application and regurgitation, two fish (numbers 41 and 42), both of which were females (580 and 590 mm fork length) tagged on September 12, 1982, exhibited characteristics that could have contributed to tag regurgitation. The fish were in "silver bright" condition and they may have been part of the Kluane River bound stocks, which migrated through the area primarily between early and mid-September. These fish appeared to "aid tag insertion" by gulping as the tag was pushed in. Although these fish travelled approximately 1,970 km in freshwater without feeding, they may have retained the ability to use their esophageal muscles thus enabling them to regurgitate the transmitter.

Two cases of net-induced mortality were suspected. One fish (number 15) stopped its upriver migration near a gillnet at km 44, and was recovered at km 5 near the original tagging site. The transmitter had slipped through the gut lining and the abrasive action of the whip antenna had lacerated the liver and spleen. The second fish (number 98) stopped its migration immediately below a gillnet located at km 176.

Three chum recaptured in the commercial fishery had internal injuries, which may have resulted from their struggles with the gillnet or may have occurred prior to recapture (which may have increased their susceptibility to recapture). In another case, a tagged fish (number 90) remained near a gillnet at km 308 (Coffee Creek) for approximately 10 days before being recaptured in a gillnet at km 314. This could indicate that the fish may have been injured by the first gillnet, or it could indicate the presence of a mainstem chum spawning area near km 308. Chum spawning near Coffee Creek was documented during a previous study (Sweitzer, 1974), but the exact location was not identified.

One other fish (number 101) may have been lost as a result of mortality induced by the effects of the tagging program. This fish may have suffered injuries when it was captured by the fishwheel.

3.2.4 Lost Transmitters and Transmitter Failures

Signal loss occurred during radio-tracking surveys of the mainstem Yukon and within the various tributaries. A summary of the final observations of six fish that were lost before they could be tracked into tributaries is presented in the following:

Fish Number	Location (km) of Last Observation	Comments
26	5	unconfirmed signal in Klondike River
32	223	signal lost below Stewart-Yukon confluence
78	182	signal lost below Sixtymile River
85	135	signal lost at tagging site
99	222	signal lost below Stewart-Yukon confluence
103	257	signal lost at mouth of White River

The signals from other fish were lost within tributaries; some had long tracking records prior to signal loss. Possible explanations for all signal losses include:

- mortality of the fish
- erratic movements of the fish
- inability of observers to distinguish radio signals from background interference
- frequency of surveys (the probability of signal loss decreases with more frequent surveys)

- transmitter frequency drift
- reduced signal transmission range resulting from the depth of the transmitter in the water, the conductivity of the water, and the orientation of the transmitter to receiving antennae
- transmitter or battery failure

The following discussion relates the preceeding factors with the six lost radio-tagged chum listed above. Fish numbers 26 and 85 were lost at their respective tagging sites. The most obvious explanation for these losses is that the fish either died or the fish moved downstream to areas below the tagging sites as a result of stress or physical injuries induced by confinement, handling, and tag implantation. Another explanation is that these fish could have initially moved upward to the tracking survey area, but then moved downstream below the area of tracking surveys. The fish that did move downstream could have subsequently resumed upstream migration and moved undetected through the tracking area. Additional explanations for initial signal loss involve transmitter or battery failure. Both factors would not be apparent unless the fish were subsequently recaptured with a non-functional transmitter.

Fish numbers 32, 78, 99 and 103 were lost between km 182 and km 257. Many of the explanations previously mentioned could also apply to these fish. Additional explanations for signal loss involve the limitations of the radio-telemetry equipment under certain conditions. It was difficult, for example, to track a large number of fish in a confined area due to limitations imposed by the frequency scan period of the receivers (maximum rate was five seconds for each transmitter frequency) and the flying speed of the aircraft. The number of frequencies programmed into the receiver was usually limited to five to seven. The pulse rate of the transmitter also influenced the ability of observers to receive signals. The fastest pulse rates (150-170 pulses per minute) were easier to distinguish than the slowest rates (20-30 pulses per minute). The amount of background static electricity (interference) was occasionally a limiting factor in signal reception. Additional limitations resulted from the depth of the transmitter in the water, the specific conductivity of the water, and the orientation of the transmitter to receiving antennae. Signal transmitter range decreased with the depth of the transmitter. Similarly, a direct relationship exists between radio transmission range and conductivity (Stasko and Pincock, 1977), because of attenuation of the radio signals. Conductivity in some tributaries (i.e. White River - 248 micromohs.cm^{-1}) was high. The orientation of the transmitter to receiving antennae was undoubtedly important in the effective signal range. "Frequency drift", a shift in transmitter frequency, occurred infrequently.

3.2.5 Biological Sampling

Male fish comprised 54.4% of the radio-tagged chum. The mean lengths of male and female chum were 672.0 mm and 596.0 mm, respectively (Table 9). The age composition of the radio-tagged chum was not determined, but because the radio-tagged sample represented a sub-sample of all fish sampled at the tagging site (see section 2.2.4), the age composition was expected to be similar to that described previously for the spaghetti program (section 2.2.4.1).

3.2.6 Tracking Results

Of the 114 radio transmitters applied, 68 were tracked into various tributaries; 28 were recaptured in commercial, domestic and subsistence fisheries (this includes one recapture which was tracked into a tributary); 13 either died or regurgitated their transmitters; and the signals from six transmitters were lost. Regurgitations were defined as those radio-tagged fish that remained sedentary at or near the tagging site.

The results of the tracking surveys were used to determine locations of spawning areas. The following sections describe the tracking survey results for six river systems: Klondike, White, Donjek and Kluane Rivers, the Yukon River mainstem, and the upper Yukon River-Teslin River area.

TABLE 9. Sex composition and fork length summary for radio-tagged chum sampled at the tagging sites, 1982.

	Females	Males
n	52	62
%	45.6	54.4
male : female	1.00	1.19
female : male	0.84	1.00
$\overline{fl}$	596.0 (n = 39)*	672.0 (n = 36)*
S.D.	33.3	45.7
Range	550.0 - 670.0	560.0 - 730.0

Where: n = number in sample; $\overline{fl}$ = mean fork length (mm);
S.D. = standard deviation

* fork lengths were not always measured during tag insertion.

3.2.6.1 Klondike River Spawning Areas

The Klondike River originates in the Tombstone Range of the Ogilvie Mountains and flows approximately 160 km to its confluence with the Yukon River at Dawson City. One radio-tagged chum was tracked into the Klondike River. This fish entered the river on September 3, 1982 and was observed 27 km up the Klondike on September 4 and 5. No observations were made between September 5 and September 24. The transmitter was recovered 44 km below the confluence of the North and South Klondike Rivers. Although the fish had been eaten by a grizzly bear, it was assumed that it had spawned. No spawning chum were observed near the radio transmitter; however, prior to being captured by the bear, the fish may have drifted downward from a farther upstream spawning site in the South Fork of the Klondike River where approximately 20 spawning chum were observed in 1981 (Osler, personal communication).

3.2.6.2 White River Spawning Areas

The White River, a glacier-fed river originating in the St. Elias Mountain Range, is confined to a canyon above the Alaska Highway, but elsewhere it is characterized by a wide flood plain with extensive braiding and many intermittent channels. The White River carries very high levels of suspended solids, which change the nature of the Yukon River below the Yukon-White confluence. Tributaries of the White River include the Koidern, Donjek and Ladue Rivers.

Chum salmon bound for the White River arrived at various White River destinations between September 12 and October 16, 1982 with the majority entering the river during late September and early October. Nine of the 15 radio-tagged chum that entered the White River were tagged between September 26 and October 3. A similar late chum run into the White River in early October was observed during a test-net operation conducted as part of the 1973 DFO tagging program (Kendel, personal communication). Peak spawning activity probably occurred in the first week of October.

Fifteen radio transmitters were tracked to locations in the White River between km 271 and km 358 (Figures 26 and 27). Six transmitters were located in the areas between km 320 and the mouth of the White River (km 266), three were located between km 325 and km 330, and six were located between km 339 and km 357.

Chum spawning habitat was investigated in a cursory manner. A field crew conducted a float survey[1] of the White River from the White-Donjek confluence to the mouth of the White River between October 8 and October 10, 1982. The objectives of the survey were to recover radio transmitters and to identify spawning locations in the river. The braided nature of the White River made it difficult to move laterally across the river; therefore, the full width of the river was not surveyed. Spawning chum salmon were not observed, although the transmitter from one fish (number one), which had been eaten by a predator (Appendix 7), was recovered in a wooded area below Home Creek. Chum spawning within the White River may be located a number of groundwater upwelling areas that were identified in a winter aerial survey (see section 2.2.5). These areas were located in sloughs well off the main channel, but were not included in the float survey because of the nature of the terrain, the extensive channel braiding, and the limitations of moving laterally across the channel during float surveys.

Although there is little available information on suspended solids levels within the White River, it is evident that suspended solids levels are lowest when chum salmon enter the river late in the fall. Juvenile chum may emerge and migrate early in the spring before peak runoff, thereby avoiding the freshet levels of suspended solids.

The results of the radio tracking surveys indicate that the White River is a more important spawning area than was expected on the basis of previously

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[1] A float survey involves observers using a boat to float downstream with the stream flow.

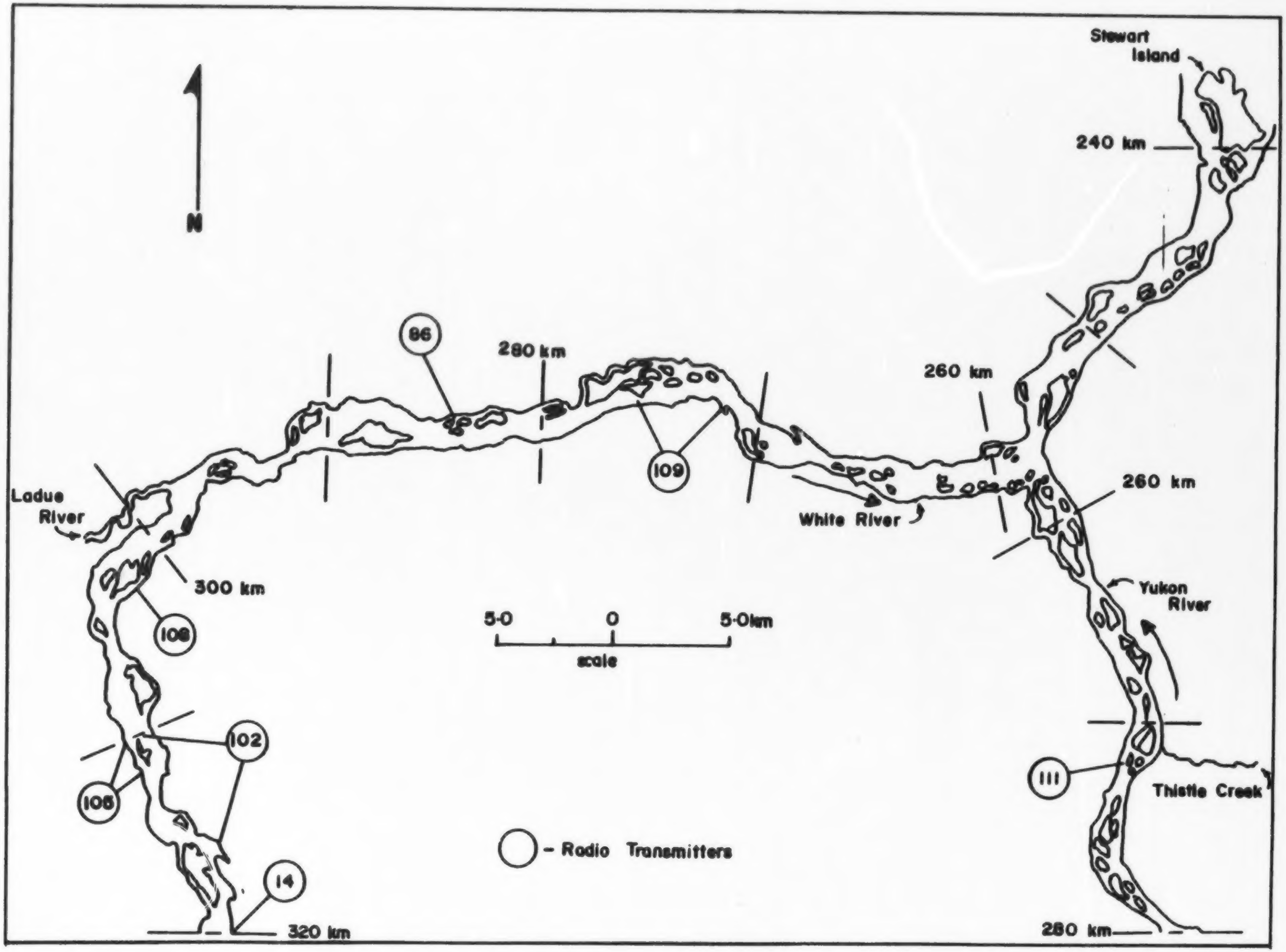
N
Stewart Island
240 km
260 km
260 km
Yukon River
Thistle Creek
280 km
White River
109
280 km
86
Ladue River
300 km
108
102
106
14
320 km
111
5-0
0
5-0km
scale
- Radio Transmitters

Figure 26 Location of radio transmitters in spawning areas on the White River between the Yukon-White confluence and km 320, 1982. Distances shown are from the lowest tagging site

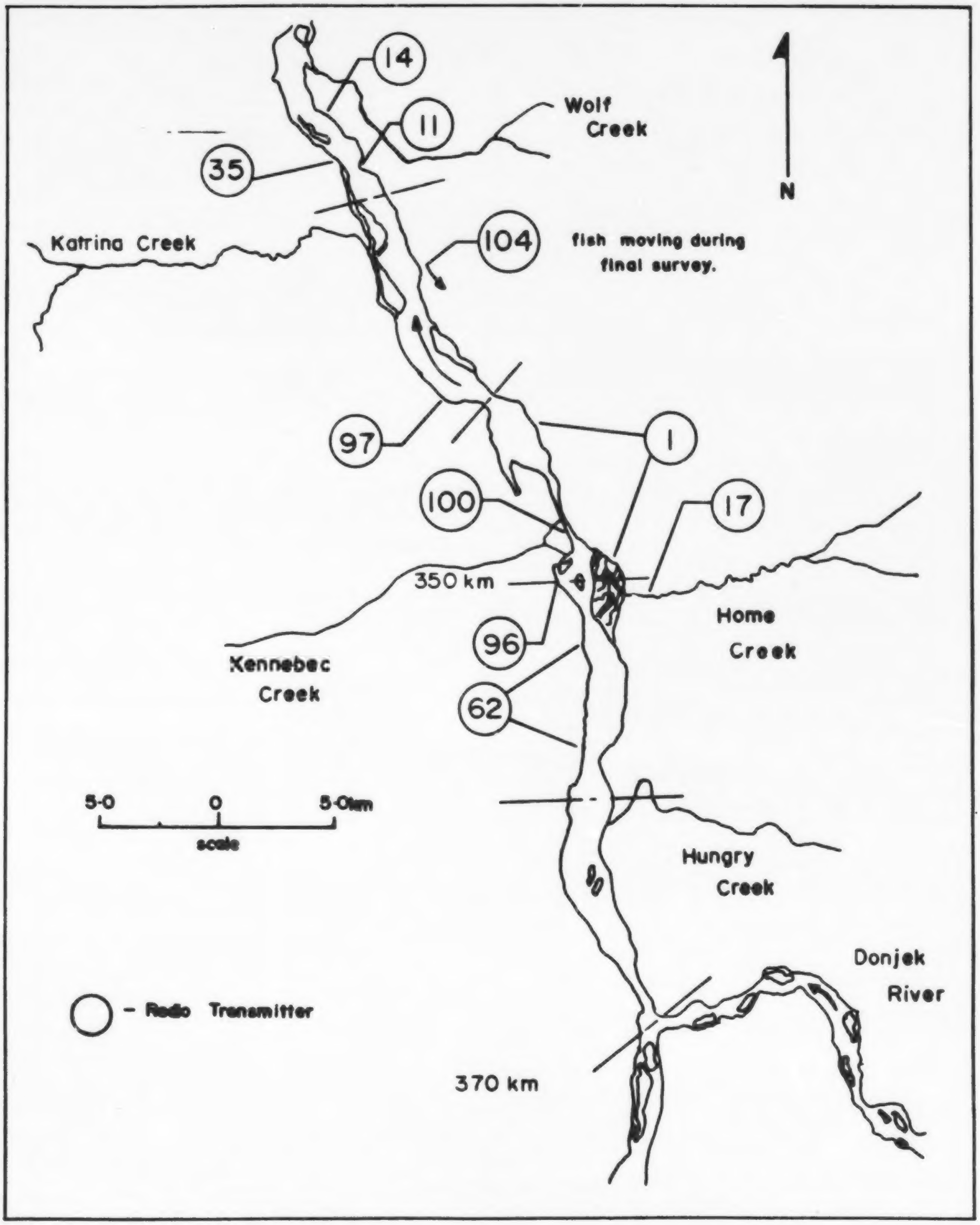
14
Wolf Creek
11
35
N
Katrina Creek
104
fish moving during final survey.
97
1
100
17
350 km
Home Creek
96
Kennebec Creek
62
5-0
0
5-0km
scale
Hungry Creek
Donjek River
- Radio Transmitter
370 km

Figure 27 Location of radio transmitters in spawning areas on the White River between km 320 and km 370, 1982. Distances shown are from the lowest tagging site

available information. However, additional surveys of this river will be necessary to provide a fuller understanding of its significance to chum production in the Yukon River Basin.

3.2.6.3 Donjek River

The Donjek River originates from the Kluane and Donjek Glaciers in the St. Elias Mountain Range and crosses the Alaska highway approximately 27 km above its confluence with the White River. The Donjek River is characterized by braided channels, sand bars, and high levels of suspended solids resulting from its glacial origin.

Eleven radio-tagged chum were tracked to the Donjek River (Figure 28). Spawning locations were not confirmed because of a lack of ground truthing, signal loss, and the continued movement of two of the fish during the final survey. The distribution of radio transmitters within the Donjek River was confined to the area between km 404 and km 485. Seven transmitters were located between km 404 and km 442 while four transmitters were located between km 462 and km 485 (Figure 28). Within the Donjek River system, previous studies (DFO files) documented chum spawning only in Wellesley Creek. Chum spawning was suspected in the lower reaches of the Nisling and Klotassin Rivers, however, radio-tagged chum were not observed in these areas in 1982.

Chum arrived at the various Donjek River locations between September 20 and October 16. During a brief helicopter survey of these areas on October 8, 1982, no spawning fish were observed, and there was no evidence of spawning in the immediate area, although one radio transmitter was recovered at km 476 in a carcass that had been eaten by a bear (Appendix 7). A test net fished for 1.5 hours at km 367 on the White River (located immediately below the Donjek River) yielded five chum (four females and one male), which were in an advanced stage of maturity and in a lethargic condition apparently lacking the energy needed to reach spawning grounds on the Kluane River. Based on an average Donjek River migration rate of 0.54 $km.h^{-1}$, it is estimated that these fish would have taken four to eight

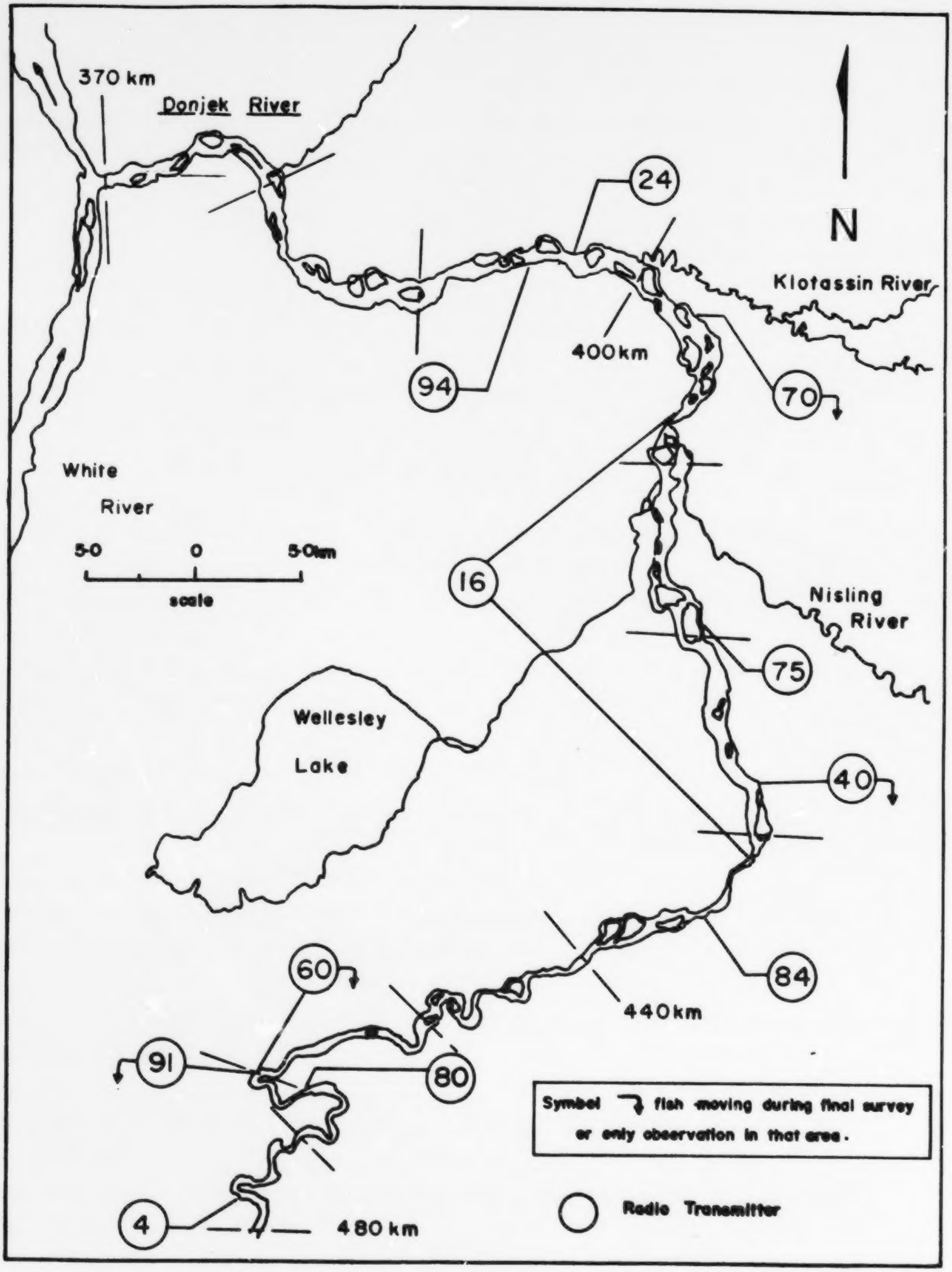
370 km
Donjek River
24
N
Klotassin River
400km
94
70
White
River
5-0
0
5-0km
scale
16
Nisling
River
75
Wellesley
Lake
40
84
60
440km
91
80
Symbol ↴ fish moving during final survey
or only observation in that area.
4
480 km
Radio Transmitter

Figure 28 Location of radio transmitters in areas on the Donjek River, 1982. Distances shown are from the lowest tagging site

days to reach the midpoints of the two principal spawning areas. This would place them in the respective spawning areas on the Donjek River between October 12 and October 16.

Spawning habitat on the Donjek river has not been investigated to any extent, partly because the area is isolated and is accessible only by helicopter or jet boat. In 1983, a spaghetti tag was recovered in a spawning area near km 462 (Appendix 3) and two additional spawning areas, both associated with upwelling groundwater, were observed near km 458 and km 462 (George Gray, personal communication).

The number of radio transmitters tracked into the Donjek River, and the identificaion of previously undocumented spawning areas, demonstrates the importance of this river. Additional surveys of the Donjek River would prove useful.

3.2.6.4 Kluane River Spawning Areas

The Kluane River, located in the south western Yukon adjacent to the Kluane Range of the St. Elias Mountains, flows over an 82 km course from Kluane Lake (the largest lake in Yukon Territory) to its confluence with the Donjek River. The upper reaches of the Kluane River are characterized by numerous braided channels, sand bars, and rapid current flow. Chum spawning areas appear to be associated with spring-fed areas of upwelling water, which have been identified in the upper reaches of this river in close proximity to the Alaska highway.

Chum arrived on the spawning grounds between September 20 and October 16, 1982, and peak spawning may have occurred during early to mid-October. Ground surveys conducted in the area between October 22 and October 26 coincided with peak die-off. The distribution of radio-tagged chum salmon that reached spawning locations on the Kluane River between km 577 and km 597 is presented in Figures 29 and 30. Fourteen radio-tagged chum were located in this area, seven between km 583 and km 585. This latter area also contained the greatest

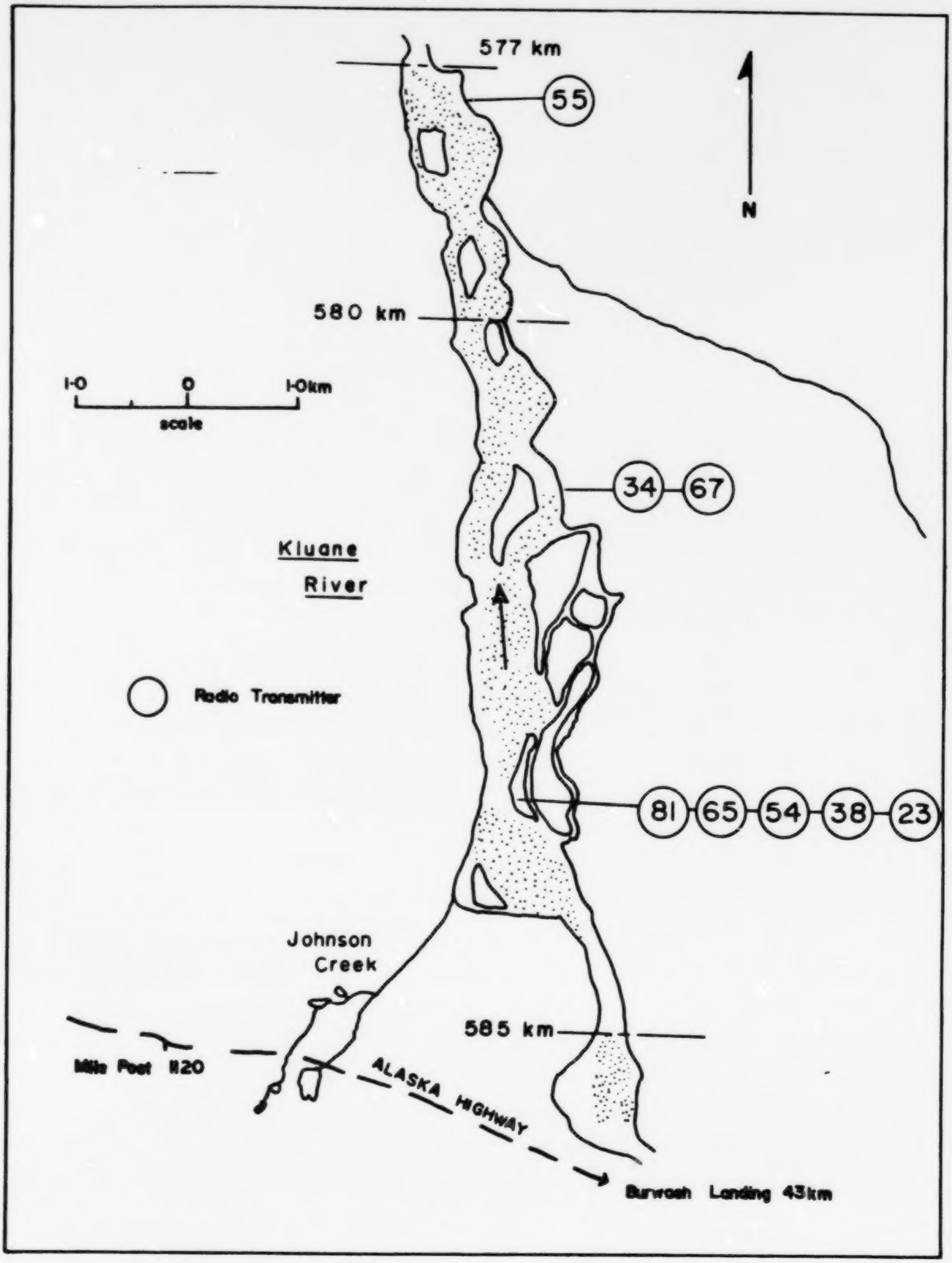
577 km
55
N
580 km
1·0
0
1·0km
scale
34
67
Kluane
River
Radio Transmitter
81
65
54
38
23
Johnson
Creek
585 km
Mile Post 1120
ALASKA HIGHWAY
Burwash Landing 43km

Figure 29 Location of radio transmitters in spawning areas along the Kluane River between km 577 and km 585, 1982. Distances shown are from the lowest tagging site

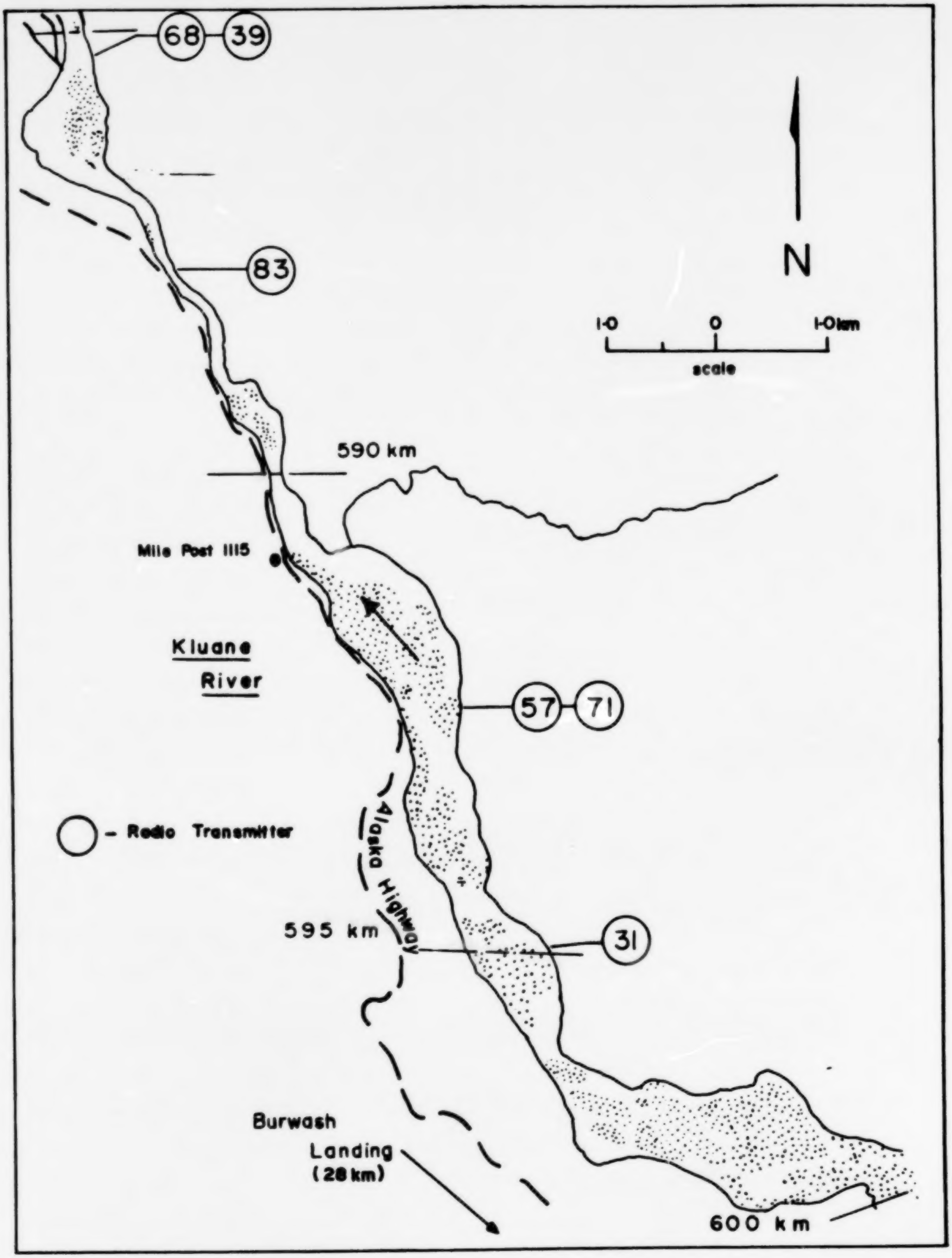
68
39
83
N
1·0
0
1·0km
scale
590 km
Mile Post 1115
Kluane
River
57
71
Radio Transmitter
Alaska Highway
595 km
31
Burwash
Landing
(28 km)
600 km

Figure 30 Location of radio transmitters in spawning areas along the Kluane River between km 585 and km 595, 1982. Distances shown are from the lowest tagging site

concentration of spawners; during an aerial survey conducted in the same area on October 14, 1982, approximately 2,700 spawning chum were counted, which represented approximately 53% of the total aerial count of Kluane River chum.

3.2.6.5 Mainstem Yukon Spawning Areas

The mainstem Yukon was defined as the section of the Yukon River between the Yukon-White confluence and an area known locally as "Yukon Crossing". This section is characterized by numerous side channels, islands, and upwelling water areas.

Twenty-three radio-tagged chum migrated to mainstem spawning areas located between km 276 (Thistle Creek) and km 476 (Yukon Crossing). The distribution of 22 of these fish is presented in Figures 26, 31 and 32 (the other fish was located in an area near Coffee Creek). The greatest concentrations of transmitters were found between km 370 and km 376 (Figure 31) and between km 432 and km 438 (Figure 32). The presence of radio transmitters was often used as an indication of spawning. In some cases, ground crews had searched these areas but had not observed spawners.

Ground searches of mainstem spawning areas were conducted in 1982 between October 5 and October 23, and in 1983, during the periods October 10-14 and October 22-25. Many areas were visited only once. The largest concentration of spawning chum salmon was located at km 416 (see section 2.2.6.2) where 800 and 3,618 spawners were observed in 1982 and 1983, respectively.

Mainstem-bound chum arrived in spawning areas between September 14 and October 16, 1982. Initial mainstem spawning probably starts during the last week of September, followed by peak spawning in early to mid-October. Ground searches of mainstem areas revealed that peak die-off occurred October 20-23, 1982 and October 14-21, 1983.

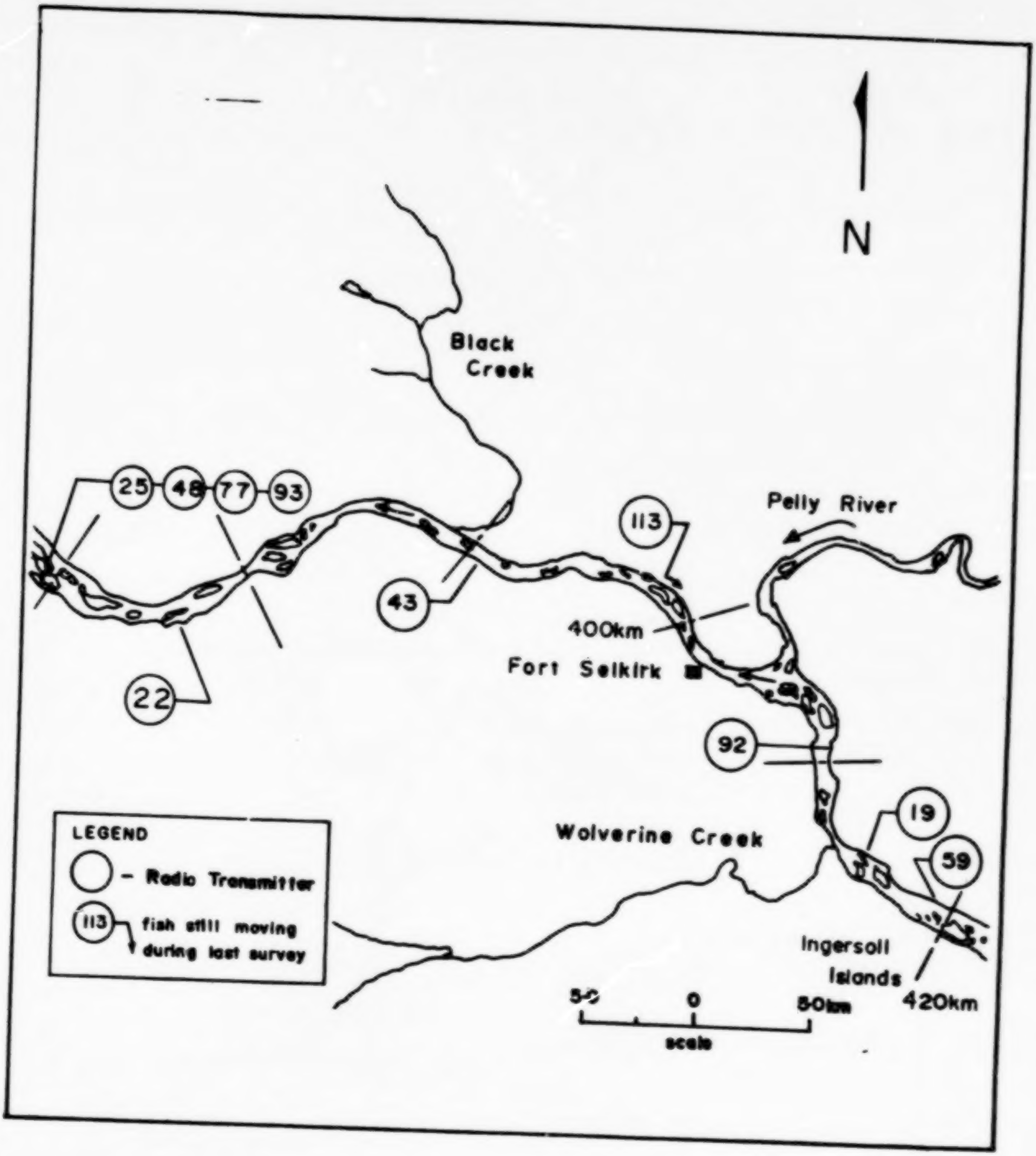
N
Black Creek
Pelly River
25
48
77
93
113
43
22
400km
Fort Selkirk
92
Wolverine Creek
19
59
Ingersoll Islands
420km
LEGEND
- Radio Transmitter
113 fish still moving during last survey
50
0
50km
scale

Figure 31 Location of radio transmitters between km 370 and the Ingersoll Islands on the mainstem Yukon River, 1982. Distances shown are from the lowest tagging site

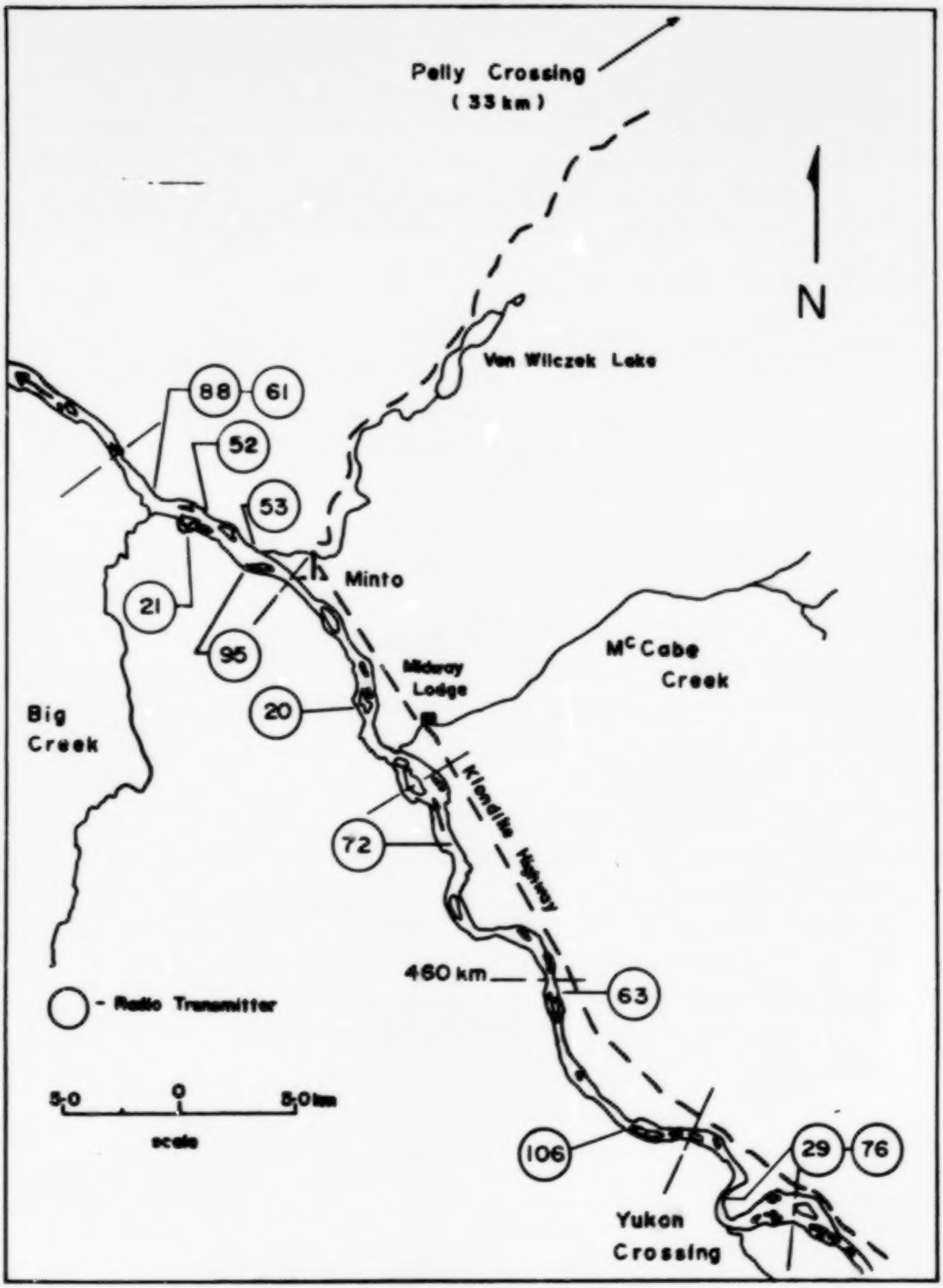
Pelly Crossing
(33 km)
N
Von Wilczek Lake
88
61
52
53
Minto
21
95
Midway
Lodge
McCabe
Creek
20
Big
Creek
Klondike Highway
72
460 km
63
- Radio Transmitter
5.0
0
5.0 km
scale
106
29
76
Yukon
Crossing

Figure 32 Location of radio transmitters in spawning areas between the Ingersoll Islands and Yukon Crossing on the mainstem Yukon River, 1982. Distances shown are from the lowest tagging site

The first radio-tagged fish to arrive in the area (fish number 21) was eaten by a bear (Appendix 7), and the transmitter was recovered in a side slough on September 22. In the same area, approximately three fresh bear kills were observed, all of which had died unspawned.

3.2.6.6 Upper Yukon-Teslin River Spawning Areas

The "upper Yukon-Teslin system" was defined as the upper Yukon and Teslin River drainage above Carmacks. The Teslin River drains Teslin Lake, the second largest lake in the territory, and flows 192 km to its confluence with the Yukon River at Hootalinqua. The upper Yukon drainage consists of the Yukon, Little Salmon, Big Salmon and Takhini Rivers and a number of large headwater lakes, including LaBerge, Bennett, Tagish, Marsh and Atlin.

Three radio transmitters were tracked to the upper Yukon-Teslin system. Two of the signals were subsequently lost, being last observed at km 608 and km 726 (Figure 33). One fish (number 36), which was tracked to a spawning site located near the mouth of the Boswell River (Figure 33), had travelled 780 km from the tagging site, and had undertaken a freshwater migration of 2,751 km, the longest recorded chum migration in North America.

Known information on chum spawning habitat in the upper Yukon-Teslin system is limited to the following:

- chum spawning has been documented in four areas, as follows:

Area	km	Source	Map Reference (1:250,000 Series)
Rabbes Slough	538	Walker (1976)	- Carmacks (115-I)
Little Salmon River	584	DFO files	- Glenlyon (105-L)
Roaring Bull Rapids area	778	DFO files	- LaBerge (105-E)
Boswell Creek area	783-786	United States Fish and Wildlife Service (1956)	- LaBerge (105-E)

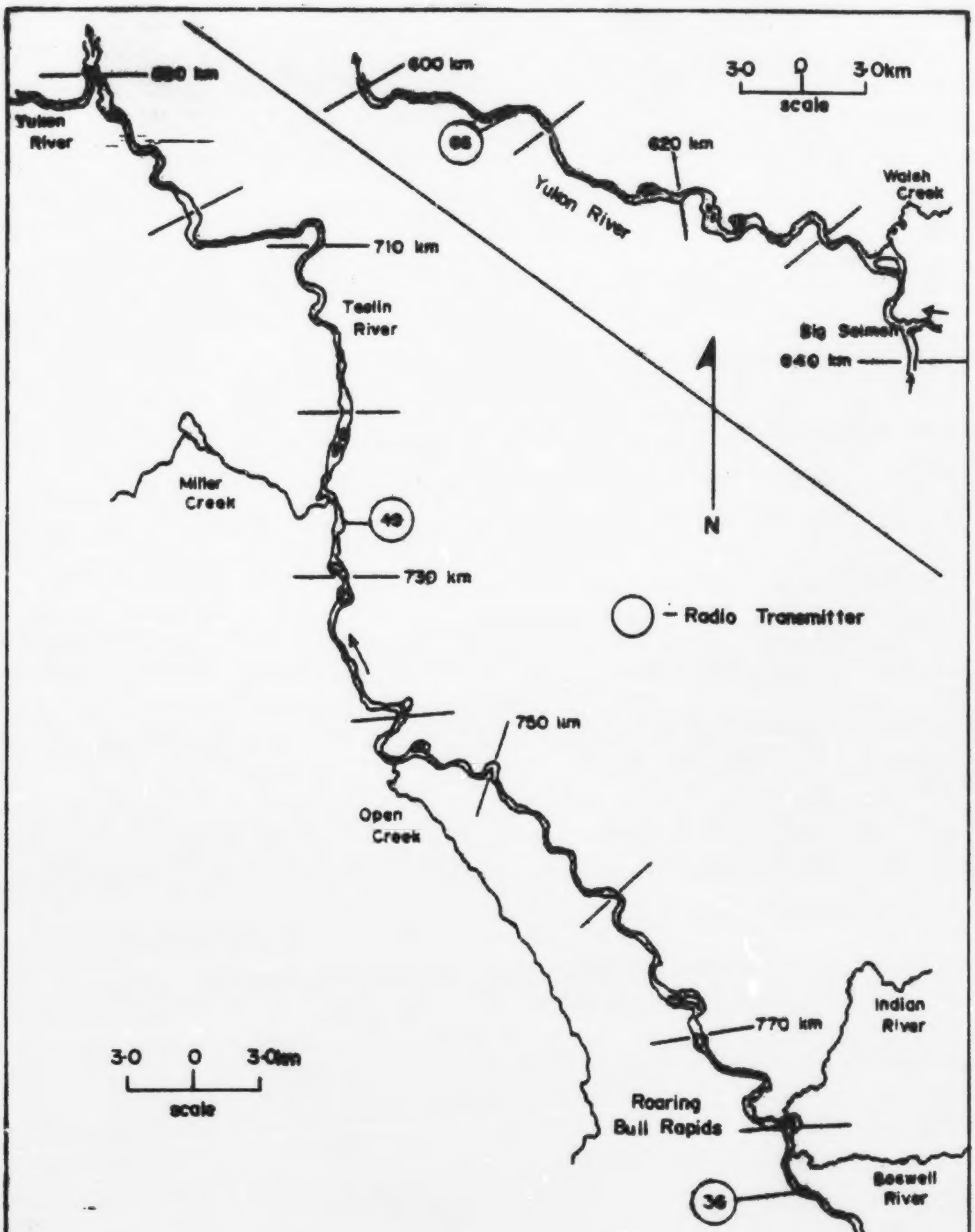
680 km
Yukon River
710 km
Teslin River
Miller Creek
48
730 km
750 km
Open Creek
770 km
Indian River
Roaring Bull Rapids
Boswell River
36
790 km
600 km
66
Yukon River
620 km
Walsh Creek
Big Salmon
640 km
3-0 0 3-0km
scale
N
○ – Radio Transmitter

Figure 33 Location of radio transmitters in upper Yukon-Teslin River areas. Distances shown are from the lowest tagging site

- during the 1983 radio-tagging program, one fish (number 30) spawned near Boswell Creek during the first week of October;
- although spawning sites are not known to exist above the Teslin River, chum have been netted in Teslin Lake (G. Krause, personal communication)

3.2.7 Migration Rates and Timing

Yukon chum salmon were arbitrarily separated into three different races based on their spawning destinations, which were the Kluane-White River system, the mainstem Yukon River (Thistle Creek-Yukon Crossing), and the upper Yukon-Teslin system (above the Yukon-Teslin confluence). The Kluane-White system was divided into three components, as follows:

White River component:	km 266 - km 370
Donjek River component:	km 372 - km 533
Kluane River component:	km 534 - km 597

The average migration rates of chum bound for the White, Donjek, Kluane, mainstem Yukon, and upper Yukon-Teslin Rivers are presented in Tables 10-14. The migration rates were calculated by assuming continuous 24-hour migration, and by excluding tracking observations that involved post-tagging delay at the tagging site. A summary of the average migration rates of the different chum races is presented in the following:

Average migration rate within each river system (km.h^{-1})

	River System				System
Destination	Yukon	White	Donjek	Kluane	Average
Kluane River	1.75	0.77	0.85	1.05	1.11
Donjek River	1.52	0.65	0.55		0.91
White River	1.53	0.65			1.09
Mainstem Yukon	1.54				1.54
Upper Yukon-Teslin	1.58				1.58
Mean	1.58	0.69	0.70	1.05	1.25

TABLE 10. Migration rates of chum salmon destined for mainstem Yukon spawning area in 1982.

FISH NUMBER	OVERALL RATE IN (KM/HR) YUKON R.	*	DATE TAGGED	ARRIVAL DATE ON SPAWNING GROUNDS	TRAVEL TIME (DAYS)	TAGGING SITE (KM)	LOCATION OF FINAL OBSERVATION (KM)	DISTANCE TRAVELLED FROM TAGGING SITE (KM)
19	1.56	12	4/9/82	18/9/82	14	5	416	411
20	1.37	13	4/9/82	18/9/82	14	5	446	451
21	1.70	11	4/9/82	14/9/82	10	5	434	429
22	1.64	8	5/9/82	16/9/82	11	5	376	371
25	1.59	10	5/9/82	15/9/82	10	5	370	365
29	1.46	13	6/9/82	20/9/82	14	5	475	465
43	1.78	8	13/9/82	22/9/82	9	5	376-392	387
48	1.41	12	13/9/82	26/9/82	13	5	370	427
52	1.73	10	14/9/82	24/9/82	10	0	432-8	438
53	1.65	10	16/9/82	27/9/82	11	5	436	431
59	1.81	9	17/9/82	27/9/82	10	5	418	413
61	1.85	9	18/9/82	28/9/82	10	5	432	427
63	1.81	9	18/9/82	1/10/82	13	5	462	457
72	1.62	6	22/9/82	1/10/82	9	135	454	319
76	1.58	7	24/9/82	9/10/82	15	135	476	341
77	1.51	6	24/9/82	1/10/82	7	135	370	235
88	1.44	5	26/9/82	7/10/82	11	135	432	297
92	1.60	5	27/9/82	7/10/82	10	135	410	297
93	1.35	4	28/9/82	7/10/82	9	135	370	235
95	1.35	5	29/9/82	9/10/82	10	135	437	302
106	1.36	4	3/10/82	16/10/82	13	135	470	335
111	1.10	3	5/10/82	12/10/82	7	135	276	141
113**	1.09	6	6/10/82	16/10/82	10	135	400	265

Mean	-	1.54 KM/HR
Range	-	1.09-1.85 KM/HR
*		Number of observations
**		Fish was still moving when last observed

TABLE 11. Migration rates of chum salmon destined for White River in 1982.

FISH NUMBER	MIGRATION RATE (KM/HR)				DATE TAGGED	ARRIVAL DATE	RECORDED TRAVEL TIME (DAYS)	TAGGING SITE (KM)	FINAL OBSERVATION (KM)	DISTANCE TRAVELLED FROM TAGGING SITE (KM)
	YUKON	*	WHITE	*						
1	1.67	3	.60	6	28/8/82	12/9/82	14	0	342	349
11	1.89	7	.75	5	1/9/82	18/9/82	17	5	325	322
14	1.55	11	.54	7	2/9/82	18/9/82	16	5	319	325
17	1.43	11	.64	6	3/9/82	18/9/82	15	5	349	344
35	1.91	5	1.12	3	8/9/82	27/9/82**	19	5	325	320
62	1.76	5	.52	7	18/9/82	8/10/82	20	5	358	353
86	1.19	3	.47	3	26/9/82	4/10/82**	8	135	285	150
96	1.58	3	.89	2	30/9/82	16/10/82	16	135	350	215
97	1.30	4	.35	5	30/9/82	13/10/82	13	135	339	204
100	1.56	3	.37	5	1/10/82	13/10/82	12	135	333	202
102	1.50	3	.65	4	2/10/82	13/10/82**	11	135	309	181
104	1.40	2	.52	7	3/10/82	16/10/82***	13	135	333	198
105	1.30	3	.86	2	3/10/82	11/10/82	8	135	309	174
108	1.46	1	.79	3	3/10/82	10/10/82	7	135	301	166
109	1.41	1	N/A		3/10/82	9/10/82	6	135	269	134
Mean -	1.53		.65	(KM/HR)						
Range -	1.19-1.91		0.35-1.12	(KM/HR)						

* Number of observations

** Estimated

*** Fish still moving

TABLE 12. Migration of chum salmon destined for Donjek River in 1982.

FISH NUMBER	MIGRATION RATE (KM/HR) YUKON	*	WHITE	*	DONJEK	*	DATE TAGGED	ARRIVAL DATE	RECORDED TRAVEL TIME (DAYS)	TAGGING SITE (KM)	FINAL OBSERVATION (KM)	DISTANCE TRAVELLED FROM TAGGING SITE (KM)
4	1.49	8	.68	8	.79	5	30/8/82	20/9/82	21	5	480	475
16	1.87	8	.79	5	.50	6	3/9/82	21/9/82	18	5	413	431
24	1.49	7	.57	6	.32	3	5/9/82	22/9/82	17	5	397	392
40+	1.96	4	.35	10	.38	3	11/9/82	10/10/82***	29	0	427	422
60	1.74	6	.58	7	.40	2	18/9/82	17/10/82**	29	5	461	455
70	1.45	5	.61	4	.90	2	21/9/82	3/10/82***	12	135	403	268
75	1.42	4	.60	4	.33	3	24/9/82	10/10/82	16	135	419	284
80	1.33	4	.69	3	.53	3	25/9/82	17/10/82**	22	135	465	330
84	1.19	3	.90	2	.85	2	25/9/82	16/10/82	21	135	433	298
91	1.73	2	1.01	3	.70	2	27/9/82	16/10/82***	19	135	461	326
94	1.05	3	.41	2	.34	1	29/9/82	16/10/82	17	135	395	260
Mean -	1.52 Km/Hr		.65 Km/Hr		.55 Km/Hr							
Range	1.05 - 1.96		0.41 - 1.01		0.32 - .90 (Km/Hr)							

* Number of observations
** Estimated
*** Still moving strongly when signal lost - may have been Kluane fish
+ Fish was still moving

TABLE 13. Migration rates of chum salmon destined for Kluane River spawning areas in 1982.

FISH NUMBER	YUKON	*	WHITE	*	DONJEK	*	KLUANE	*	DATE TAGGED	ARRIVAL DATE ON SPAWNING GROUNDS	RECORDED TRAVEL TIME (DAYS)	TAGGING SITE (KM)	FINAL OBSERVATION (KM)	DISTANCE TRAVELLED FROM TAGGING SITE (KM)
23	2.03	6	1.01	5	1.10	5	1.54	2	5/9/82	20/9/82	15	5	511	506
31	2.12	4	1.24	3	1.03	5	1.29	1	7/9/82	25/9/82	18	5	595	590
34	1.76	6	.82	5	.80	5	.53	2	8/9/82	2/10/82	24	5	581	578
37	1.86	4	.93	6	.87	5	.98	2	10/9/82	2/10/82	22	5	592	595
38	1.99	5	.67	7	1.05	5	1.21	1	10/9/82	3/10/82	23	5	583	579
39	1.41	6	.60	6	.83	5	.62	1	10/9/82	8/10/82	28	5	584	590
54	1.70	6	.50	2	.64	2	N/A		16/9/82	19/10/82**	33**	5	584	579
55	1.88	1	.54	3	.68	2	.82	1	16/9/82	12/10/82**	28**	5	577	572
65	1.59	4	.59	5	.81	2	1.15	1	19/9/82	13/10/82	24	135	583	448**
67	1.82	3	.73	6	.92	2	1.11	1	20/9/82	8/10/82	18	135	581	446
68	1.41	4	.68	5	.86	2	1.48	2	20/9/82	10/10/82	20	135	585	450
71	1.63	4	.87	5	.88	2	.71	1	21/9/82	13/10/82	22	135	589	456
81	1.73	3	.80	3	.86	2	1.08	1	25/9/82	16/10/82	21	135	583	448
83	1.79	3	.81	2	.90	2	1.09	1	25/9/82	16/10/82**	21	135	587	452
87	1.58	3	.72	3	.52	4	N/A		26/9/82	13/10/82	18	135	451	316

Mean - 1.75 KM/HR .77 KM/HR .85 KM/HR 1.05 KM/HR
Range - 1.41-2.12 0.50-1.24 0.52-1.10 0.53-1.54 (KM/HR)
* Number of observations
** Estimated values

TABLE 14. Migration rates of chum salmon destined for upper Yukon and Teslin River spawning areas in 1982.

FISH NUMBER	MIGRATION RATE (KM/HR) YUKON	*	DATE TAGGED	DATE OF LAST OBS.	RECORDED TRAVEL TIME (DAYS)	TAGGING SITE (KM)	FINAL OBSERVATION (KM)	DISTANCE TRAVELLED FROM TAGGING SITE (KM)
36	1.65	10	10/9/82	14/10/82	34	5	785(T)	780
66**	1.43	10	19/9/82	4/10/82	15	135	608	473
49***	1.65	13	14/9/82	7/10/82	23	5	726(T)	721

Mean - 1.58 (KM/HR)
Range - 1.43-1.65 (KM/HR)
* Number of observations
** Still moving during last observation
*** Fish may have been close to spawning area since migration rate had slowed
(T) Fish within Teslin system

The migration rate of Kluane bound chum in the Yukon River was significantly faster (1.75 ± 0.12 $km.h^{-1}$) (ANOVA: F(14,63) = 3.2, $p<0.05$) than rates for other chum travelling within the Yukon River portion of their migration. There was no significant difference in migration rates of Kluane bound chum in the White River (0.77 $km.h^{-1}$) or the Donjek River (0.85 $km.h^{-1}$), however, these rates were significantly slower than their migration rates in the Kluane River (1.05 $km.h^{-1}$) and Yukon River (1.75 $km.h^{-1}$) (ANOVA: F(2,41) = 3.23, $p<0.05$).

The overall mean migration rates in the Yukon, White, Donjek, and Kluane Rivers were analyzed by a multiple range test using 99% confidence limits. There was no significant difference between the overall migration rates in the White River (0.69 $km.h^{-1}$) and the Donjek River (0.70 $km.h^{-1}$), however, all other differences were significant (F (13,120) = 167.4, $p<0.01$).

Glacial inflow into the White and Donjek Rivers had an obvious effect on chum migratory behaviour within these rivers. The high level of suspended solids associated with these rivers appeared to reduce migratory rates. A similar effect was evident below the Yukon-White confluence during the 1983 chinook return (Milligan et al. 1984).

3.2.7.1 Overall Migration Rate of Chum in the Yukon River

The average migration rate of the 68 tributary bound chum travelling in the Yukon River portion of their migration was 1.58 $km.h^{-1}$ (range 1.05 to 2.12 $km.h^{-1}$) and the average distance covered during daily migration, therefore, was 37.9 km and the range was 25.2 to 50.9 $km.day^{-1}$. The rates determined from this radio telemetry program were among the highest recorded for Yukon chum salmon (Table 15). The average migration rate was substantially higher than rates determined from other fishwheel tag-recovery programs conducted in the Dawson area. As a result of the spaghetti tagging component of this study (see section 2.2.7), migration rates of 30.5 and 31.6 $km.day^{-1}$ were determined for 1982 and 1983, respectively, and based on a 1974 study using Petersen disc tags, a migration rate of 28.4 $km.day^{-1}$ was determined (Brock 1976). In Alaska, the fastest

TABLE 15. Comparative migration rates of Yukon River chum salmon.

Migration Rate (km/day)		
Average	**Range**	**Source**
33.6	N/A	Trasky (1971) as cited in Brock (1976)
N/A	21.9 - 29.1	1972, 1973 Rampart Studies as cited in Mauney (1979)
N/A	21.9 - 25.9	1976, 1977 Mid-Yukon Studies as cited in Mauney (1979)
40.3	N/A	A.D.F. & G. Annual Report (1964)
28.4	20.2 - 33.8	Brock (1976)
34.5	N/A	Mauney (1979)
37.9	25.2 - 50.9	Chum radio tagging program (1982)

documented rate of chum migration in a similar radio-tagging study conducted on the Susitna River was 38.4 $km.day^{-1}$ (Krueger, personal communication). A more typical rate from subsequent observations of the same Susitna River chum was 26.2 $km.day^{-1}$.

3.2.7.2 Klondike River

The lone chum that entered the Klondike River had an average migration rate of 2.1 $km.h^{-1}$ (50.4 $km.day^{-1}$) in the Yukon portion of its migration and 0.78 $km.h^{-1}$ within the Klondike River. This fish was tagged on August 31, 1982, and arrived at a spawning area during the first week in September.

3.2.7.3 White River

Chum bound for the White River had an average migration rate of 1.53 $km.h^{-1}$ (36.7 $km.day^{-1}$) in the Yukon portion of their migration and 0.65 $km.h^{-1}$ within the White River (Table 11). The Yukon River rate was lower than the rate determined for Kluane-bound fish and it was similar to the rate recorded for Donjek River fish.

White River chum were tagged between August 28 and October 3, 1982; 57% of the sample was tagged between September 30 and October 3. This suggests that the majority of White River chum migration occurs near the end of the run. White River chum arrived on the spawning grounds between mid-September and mid-October. The daily tracking records for chum bound for the White River are presented in Figures 34a and 34b.

3.2.7.4 Donjek River

Chum bound for the Donjek River had an average migration rate of 1.52 $km.h^{-1}$ (36.5 $km.day^{-1}$) when travelling in the Yukon portion of their migration, rates of 0.65 and 0.55 $km.h^{-1}$ when in the White and Donjek Rivers, respectively (Table 12), and an overall migration rate of 0.91 $km.h^{-1}$. All Donjek River migration rates were lower than those recorded for the chum bound for Kluane River.

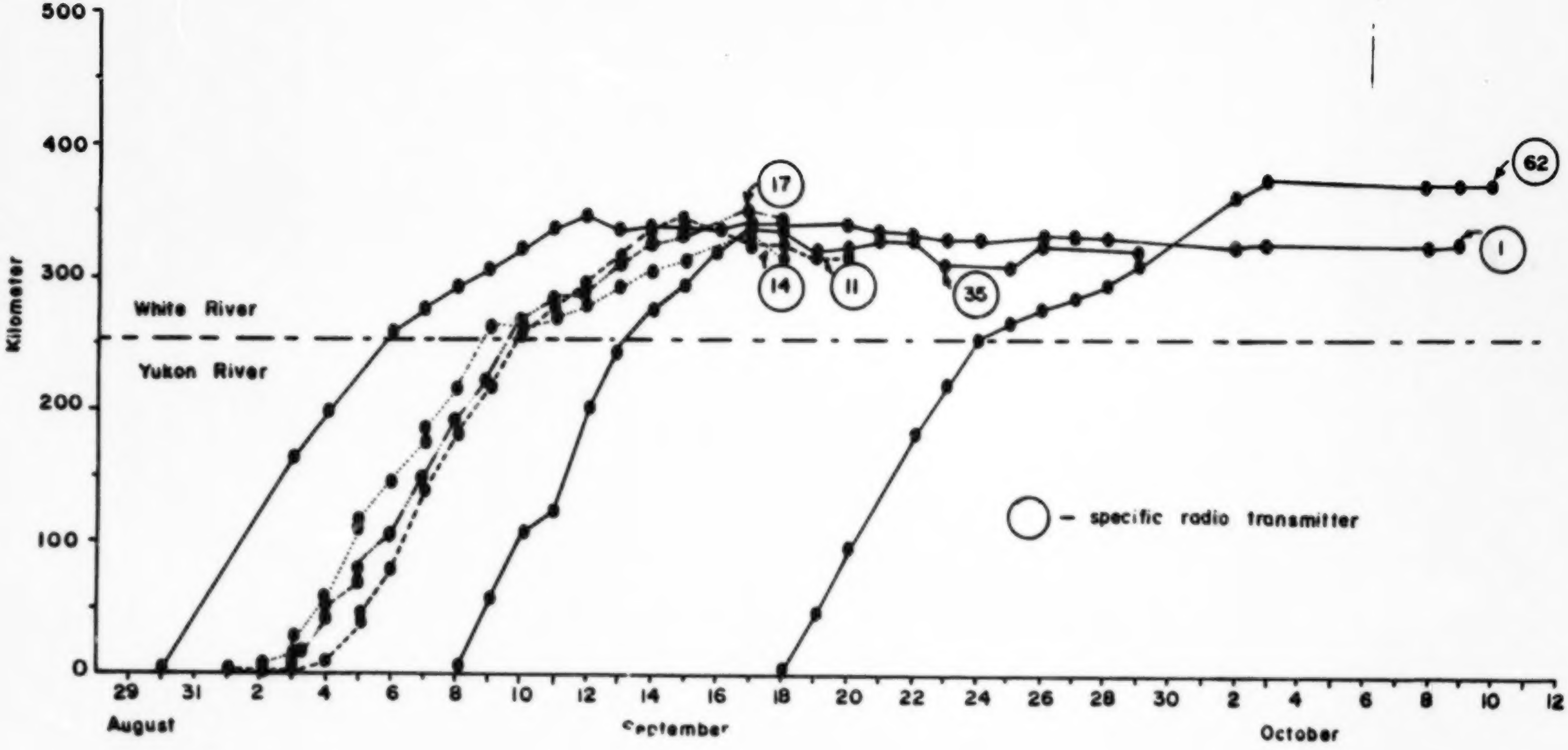

Figure 34a Radio tracking records of chum bound for the White River, 1982. Distances shown are from the lowest tagging site

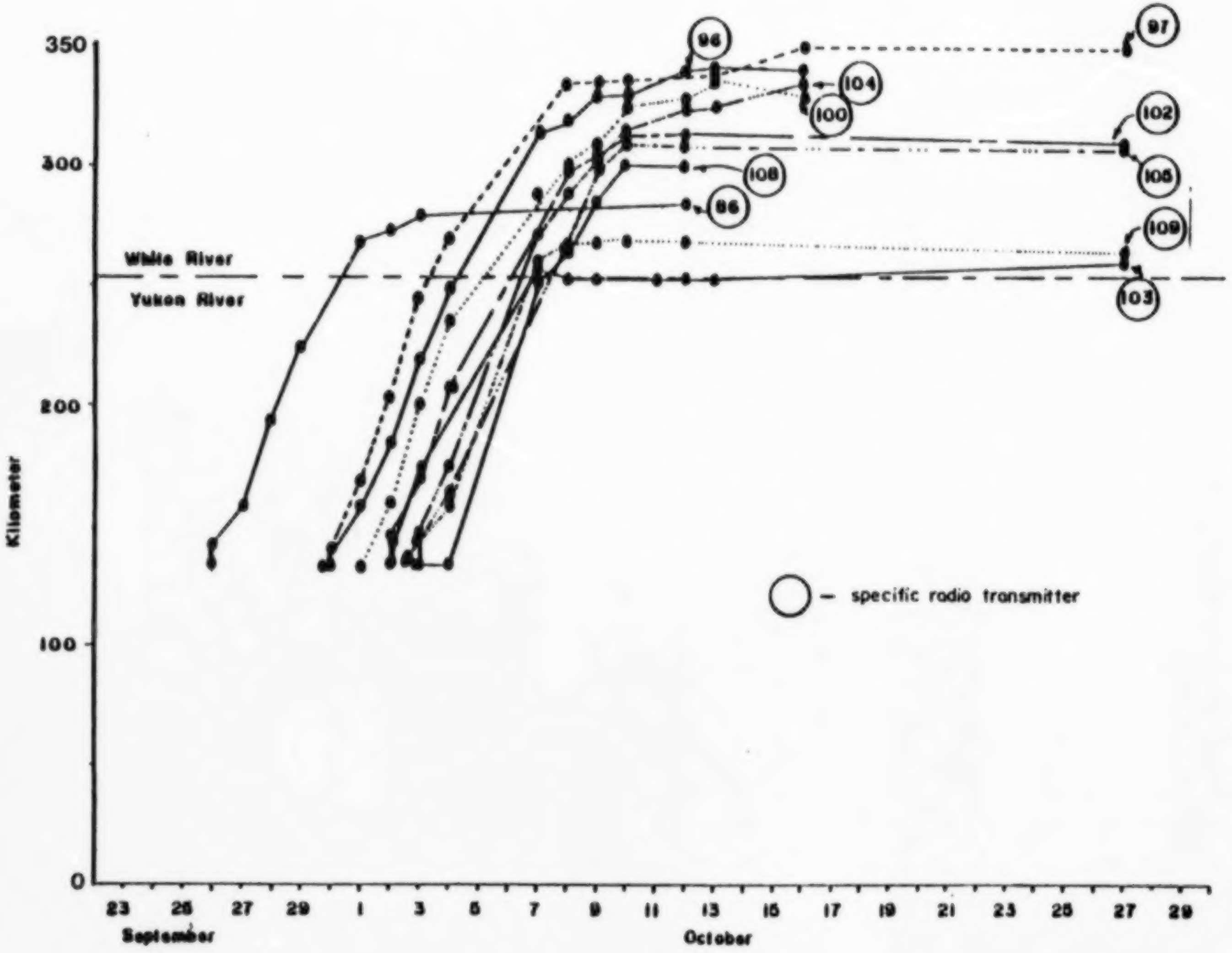

Figure 34b Radio tracking records of chum bound for the White River, 1982. Distances shown are from the lowest tagging site

Donjek River fish were tagged between August 30 and September 29, 1982 and arrived in spawning locations between September 20 and mid-October. The daily tracking records of chum bound for the Donjek River are presented in Figures 35a and 35b.

3.2.7.5 Kluane River

Chum bound for the Kluane River had the highest recorded migration rate (1.75 $km.h^{-1}$ - 42.5 $km.day^{-1}$) when travelling in the Yukon portion of their migration. The average migration rate dropped to 0.77 $km.h^{-1}$ in the White River and subsequently increased to 0.85 and 0.97 $km.h^{-1}$ in the Donjek and Kluane Rivers respectively (Table 13). The overall migration rate was 1.11 $km.h^{-1}$. Migration rates within the White and Donjek Rivers were undoubtedly influenced by the turbid nature of the water. Outflow from the White system changes the nature of the Yukon River below the Yukon-White confluence. Bank orientation and reduced migration rates were evident for Kluane River fish when they were well below the Yukon-White confluence and in the plume of the White River they usually migrated along the left bank.

Kluane River chum were tagged between September 5 and September 16, 1982 and arrived on the spawning grounds between September 20 and mid-October. The daily tracking records for Kluane bound chum are presented in Figures 36a and 36b.

3.2.7.6 Mainstem Yukon

Chum bound for mainstem Yukon spawning areas had an average migration rate of 1.54 $km.h^{-1}$ (37 $km.day^{-1}$) (Table 10). These fish were tagged between September 4 and October 6, 1982 and arrived in spawning areas between September 18 and October 16. The daily tracking records for mainstem-bound chum are presented in Figures 37a and 37b.

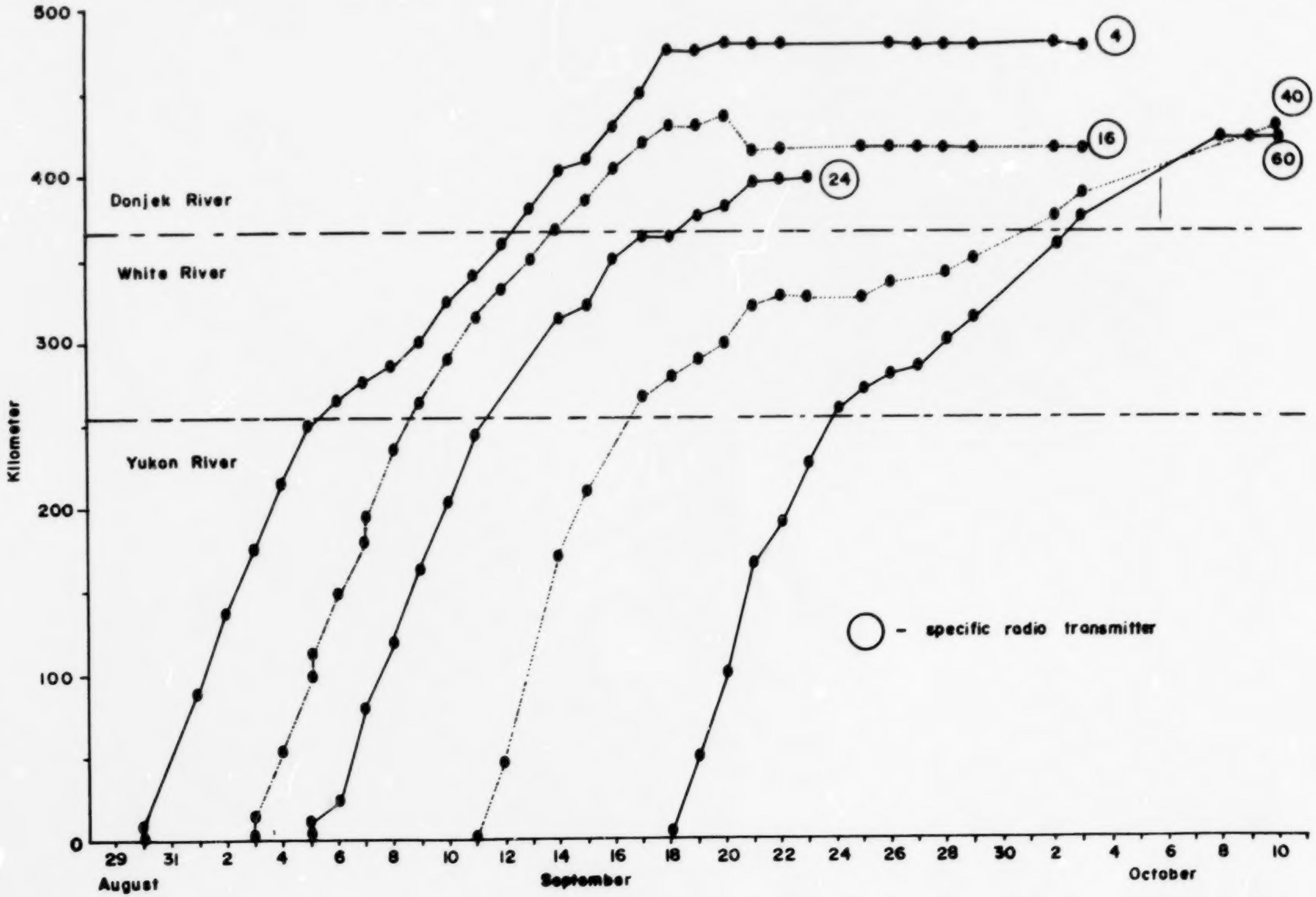

Figure 35a Radio tracking records of chum bound for the Donjek River, 1982. Distances shown are from the lowest tagging site

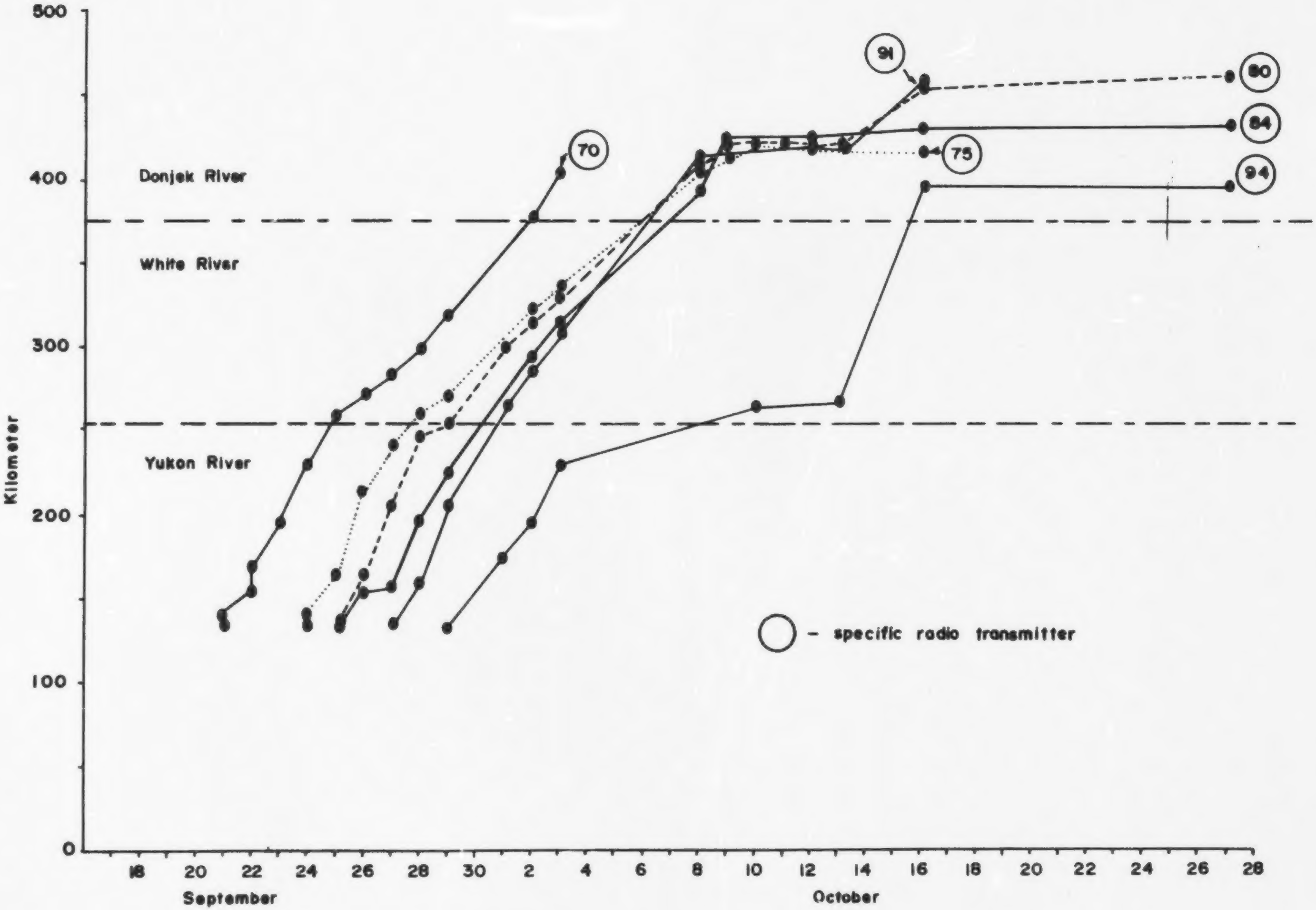

Figure 35b Radio tracking records of chum bound for the Donjek River, 1982. Distances shown are from the lowest tagging site

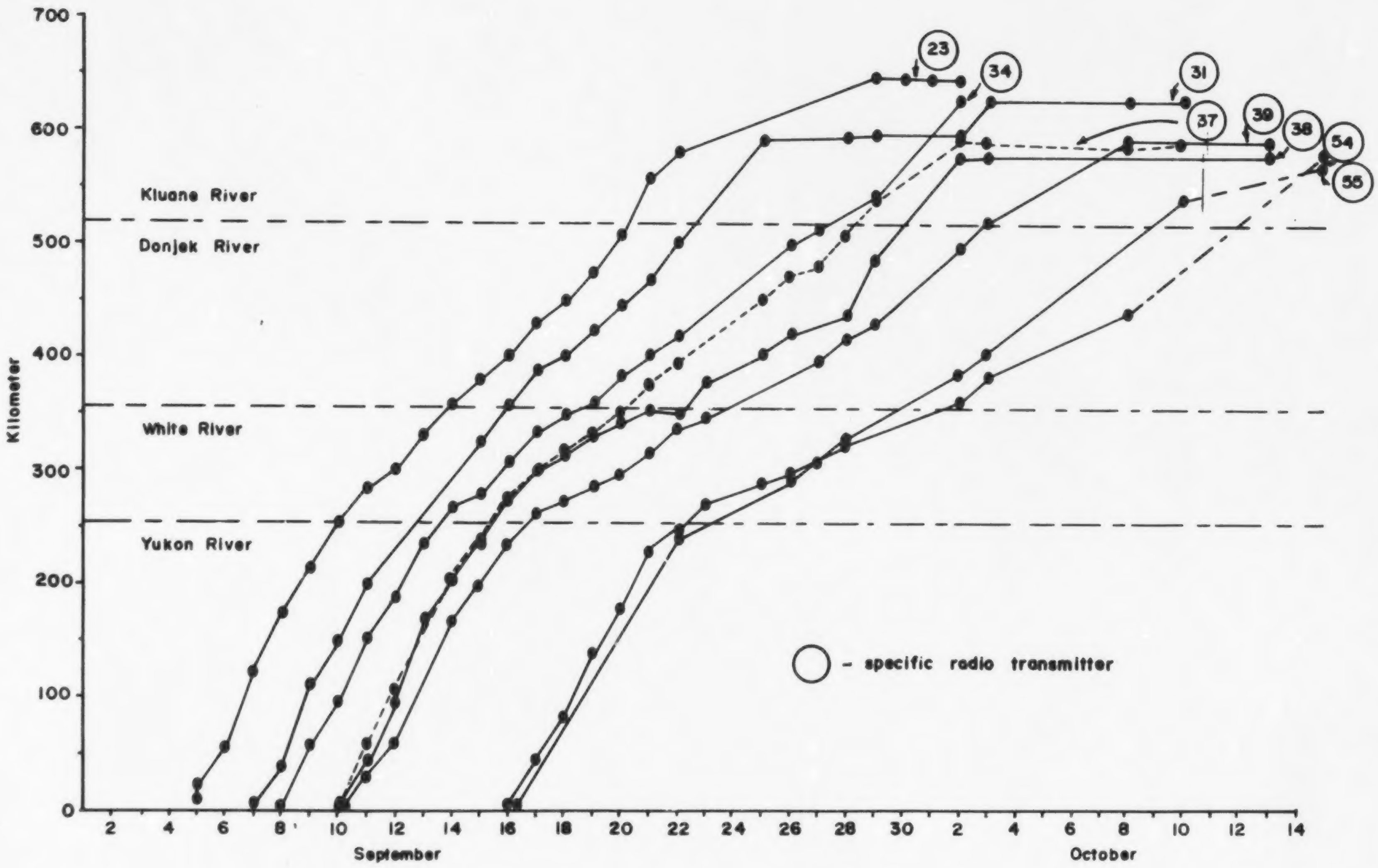

Figure 36a Radio tracking records of chum bound for the Kluane River, 1982. Distances shown are from the lowest tagging site

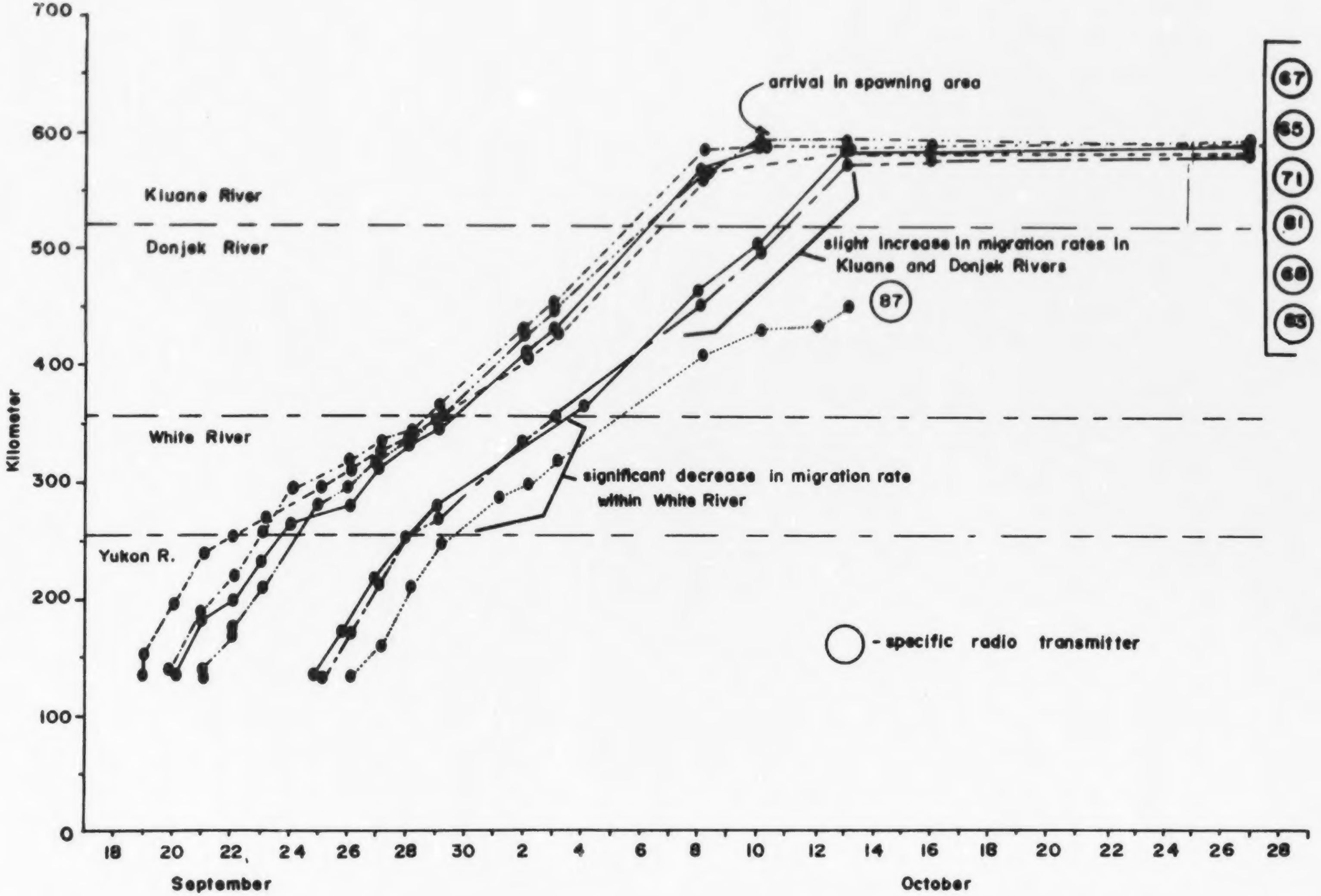

Figure 36b Radio tracking records of chum bound for the Kluane River, 1982. Distances shown are from the lowest tagging site

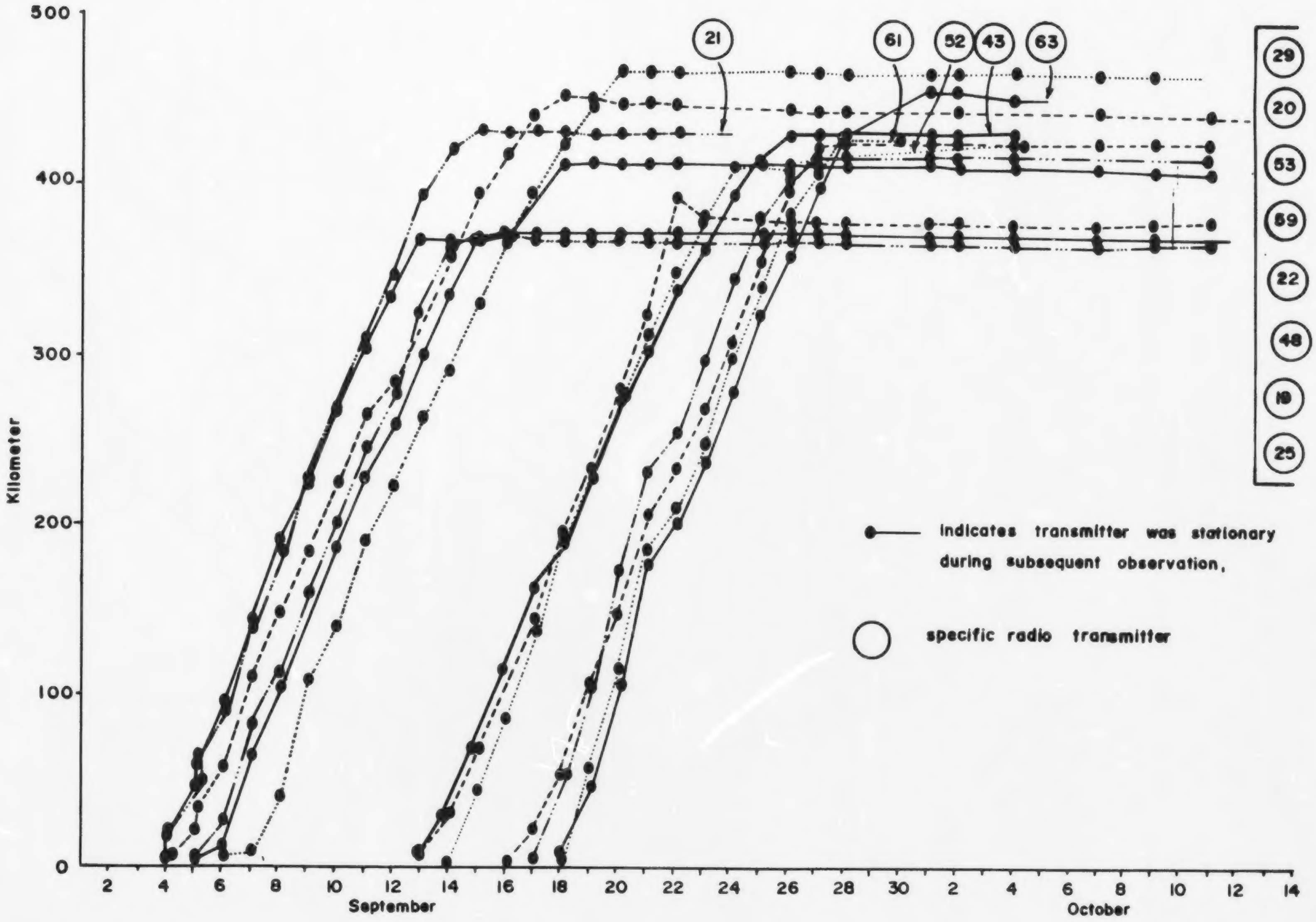

Figure 37a Radio tracking records of chum bound for the mainstem Yukon, 1982. Distances shown are from the lowest tagging site

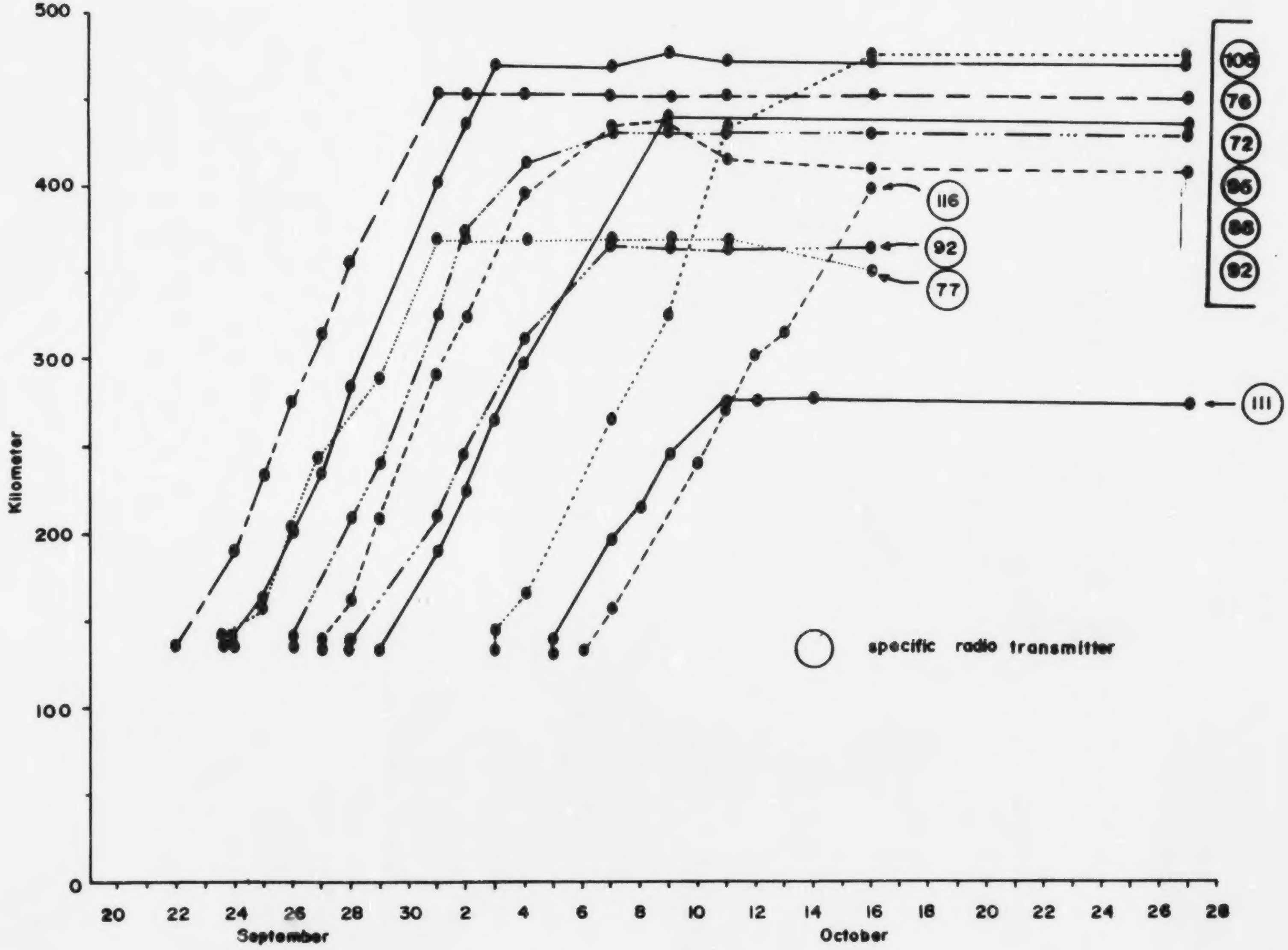

Figure 37b Radio tracking records of chum bound for the mainstem Yukon, 1982. Distances shown are from the lowest tagging site

3.2.7.7 Upper Yukon - Teslin River

Chum bound for the upper Yukon and Teslin drainages had an average migration rate of 1.58 $km.h^{-1}$ (38.0 $km.day^{-1}$) (Table 14). These fish were tagged September 10-19, 1982. One fish was tracked to a spawning area at km 785, while the other two fish were lost. The infrequency of observations precluded the determination of migration rates within the Teslin River system itself. The daily tracking records for upper Yukon and Teslin Rivers bound are presented in Figure 38.

3.2.8 Stock Separation and Chum Production within Sub-basins

Kluane bound chum were determined to be a distinct stock having a temporal difference in migration timing and, as indicated previously, a significantly different migration rate (1.75 ± 0.12 $km.h^{-1}$, $p < 0.05$) in the Yukon River portion of their migration. These fish migrated through the commercial fishery near Dawson City between September 5 and September 26, 1982 (Figures 36a and 36b) (Table 13), which corresponds with a distinct peak in chum abundance in commercial and fishwheel tagging site catches in 1982 and 1983 (Figures 22 and 23). In both years, the peaks occurred in the first two weeks of September, during the early part of the run. This early migration of Kluane-bound chum was also apparent from the spawning ground recoveries of spaghetti tags that had been applied between August 21 and September 15, 1983 (Figure 39). Although Kluane-bound chum may migrate at an earlier or later date in any given year, it appears that they are part of the first pulse of chum to pass through the Dawson area.

Radio-tagged chum were tracked into three principal areas, the White sub-basin, mainstem Yukon, and upper Yukon-Teslin system. The number of radio-tagged chum which travelled into each of these areas was as follows: -

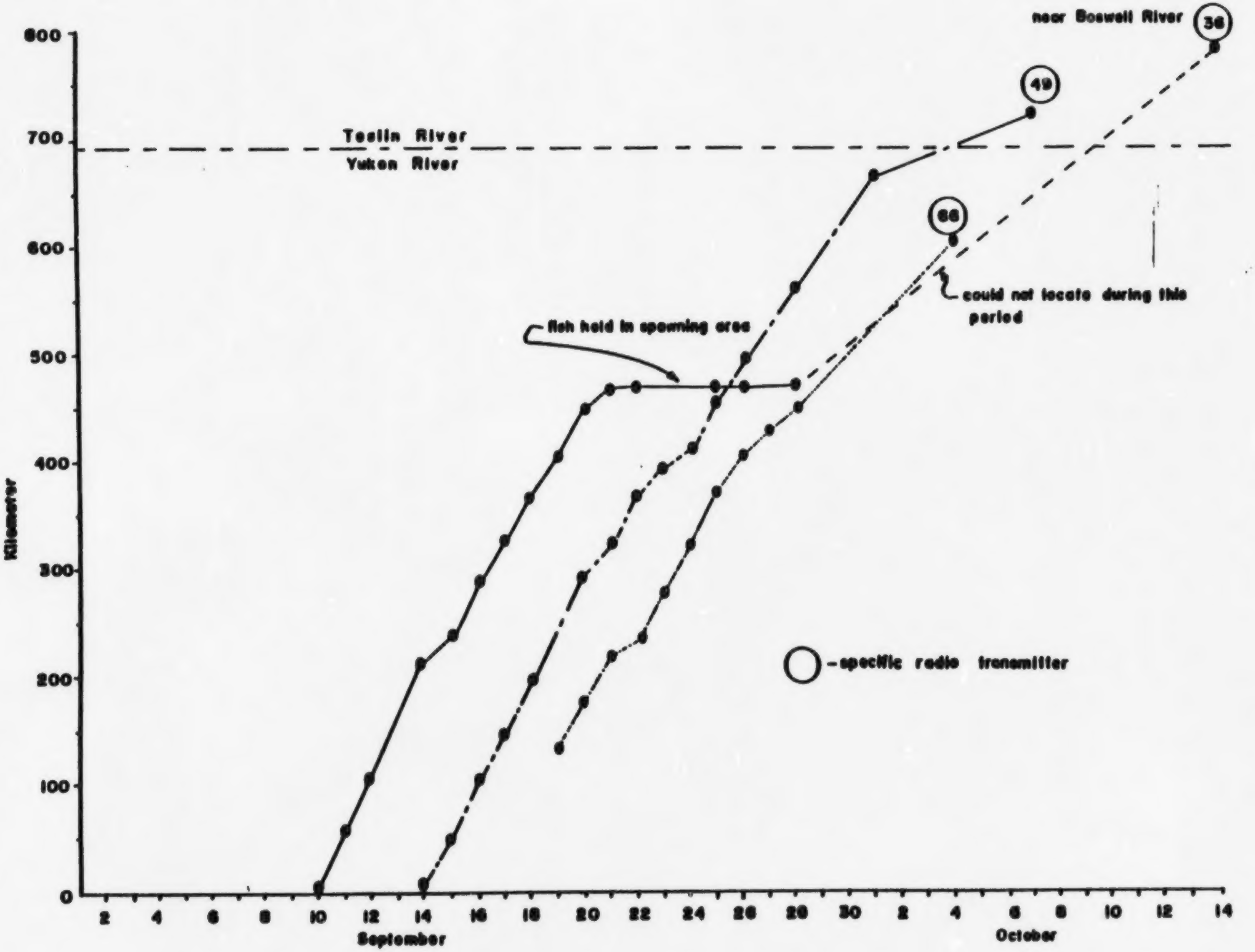

Figure 38 Radio tracking records for chum bound for the upper Yukon and Teslin Rivers, 1982. Distances shown are from the lowest tagging site

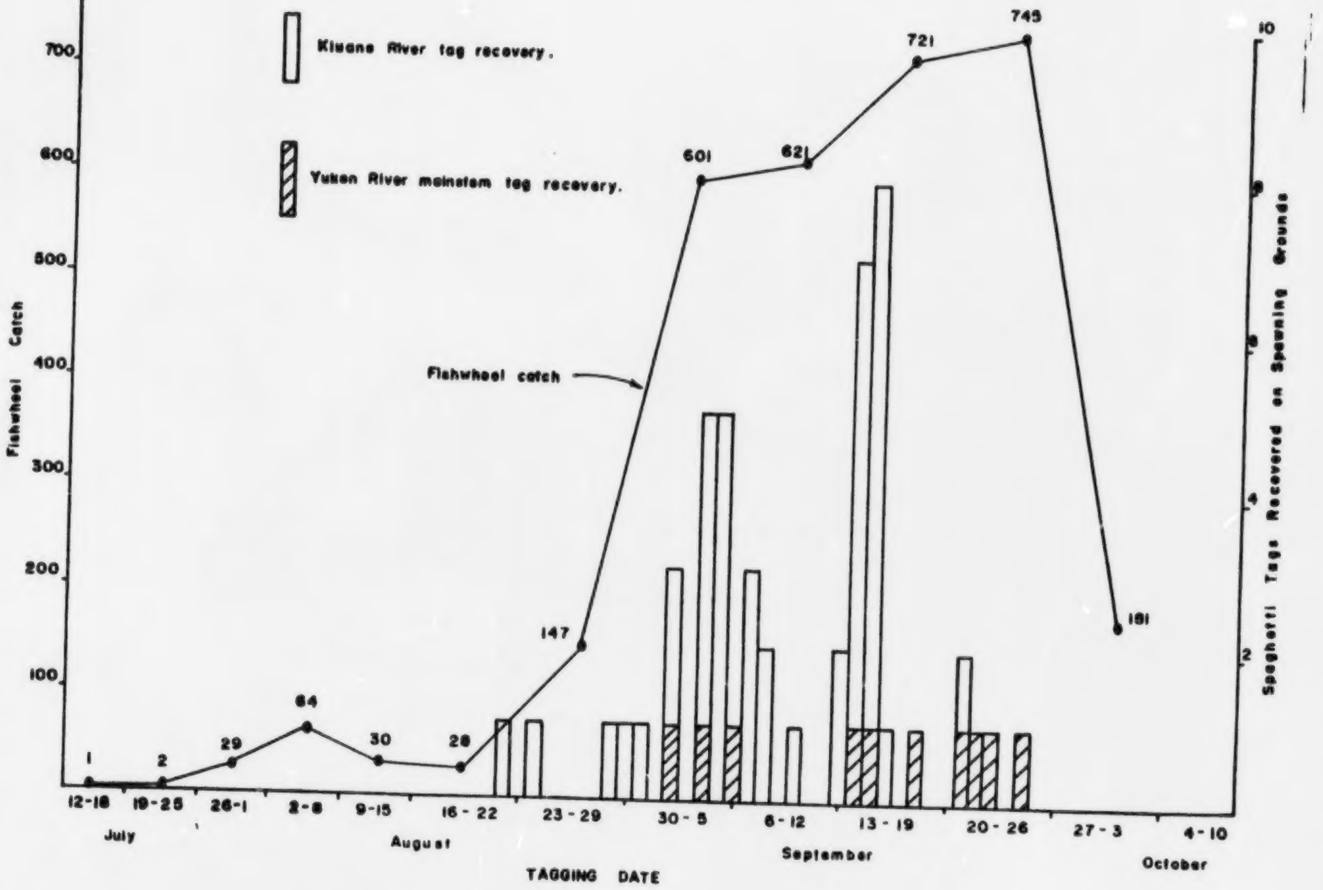

Figure 39 Spaghetti tags recovered in the Kluane and mainstem Yukon spawning grounds

Area	Number of Transmitters	Percentage of Total
Kluane-White	41	60
Mainstem Yukon	23	34
Upper Yukon-Teslin	3	4
Klondike River	1	2
Total	68	100

In determining estimates of chum production within the various sub-basins, several difficulties related to the sampling methodology were encountered. One problem was that radio-tagging is a qualitative, rather than a quantitative, method and a second problem was that a small sample size was used for implanting transmitters. A third problem was the variation in the ratios of radio-tagged fish to untagged fish throughout the chum migratory period. The tagging effort, for example, was lowest during peak migration, which occurred in a two-week interval between September 21 and October 4 (Table 16). The tagged to untagged ratios for escapement fish during the first and second weeks were 1:970 and 1:719, respectively.

Based on the Schaefer population estimate, 24,000 chum or 65% of the total run migrated through the Dawson area in this period (Table 16). The final destinations of radio-tagged chum were almost equally divided between the mainstem Yukon and the Kluane-White system between September 21 and October 4, 1982. A total of 51.3% of the radio-tagged chum migrated to mainstem spawning sites. The remainder (48.7%) entered the White sub-basin. Based on the radio-tagging information, the majority of chum production in the upper Yukon River basin in 1982 occurred in the White sub-basin.

TABLE 16 Transmitter applications, recoveries and tagged - untagged ratios in and above Dawson area fishery

Week	Time Interval	Chum Population (Schaefer Method)	Dawson Area Chum Catch	Escapement Above Dawson Area	Radio Transmitter Applications	Tagged:Untagged Ratio *	Transmitter Recoveries In Dawson Area Fishery	Regurgitated Or Lost Trans. Dawson Area	Radio Transmitters Above Stewart River	Tagged:Untagged Ratio **
1	Aug 24-30	N/A	14	N/A	6	N/A	4	0	2	N/A
2	Aug 31-Sept 6	5,534	1,422	4,112	23	1:241	8	3	12	1:343
3	Sept 7-13	6,060	1,800	4,260	19	1:319	6	3	10	1:426
4	Setp 14-20	5,401	1,317	4,084	20	1:270	2	3	15	1:272
5	Sept 21-27	17,901	3,350	14,551	24	1:746	4	5	15	1:970
6	Sept 28-Oct 4	11,578	2,231	9,347	18	1:643	1	4	13	1:719
7	Oct 5-11	575	123	452	4	1:144	0	1	3	1:151
Total		47,049	10,243	36,806	114	Mean 1:394 Range 144-746	25	19	70	Mean 1:480 Range 151-970

* Ratio of total chum population to total number of transmitters applied

** Ratio of total chum escapement above Dawson Area Fishery to escapement of radio-tagged fish above Dawson Area Fishery.

4.0 DISCUSSION AND RECOMMENDATIONS

4.1 Review of Tagging Techniques

Two types of tagging techniques were used in this study. Spaghetti tags were applied to determine quantitative information, which included population estimates and exploitation rates. Radio transmitters were applied to determine more qualitative information such as migratory behaviour, stock separation, and the location of spawning areas. Information from spaghetti tagging is dependent upon the subsequent recapture of the fish whereas radio-tagging provides continuous information after the tag is applied. The radio tracker essentially becomes a passive observer and recorder of the fish's movements. A summary of the major differences in the tagging techniques appears in Appendix 8.

A number of requirements or conditions of mark-recapture studies, which are applicable to the spaghetti tagging program, include the following (cited from Ricker 1975):

1. The marked fish suffer the same natural mortality as the unmarked fish.

2. The marked fish are as vulnerable to the fishing being carried on as the unmarked ones.

3. The marked fish do not lose their mark.

4. The marked fish become randomly mixed with the unmarked, or the distribution of the fishing effort (in subsequent sampling) is proportional to the number of fish present in different parts of the body of water.

5. All marks are recognized and reported on recovery.

In general, the chum spaghetti tagging program fulfilled the preceding requirements. The age composition of the chum tagged was almost identical to that in the commercial fishery (recovery sample), although selective factors altered the size and sex composition. Chum were susceptible to capture by fishwheels because they migrated in shallow water close to the shoreline. The tagged fish appeared to retain their tags and mix randomly with the untagged fish. Many tags were observed and/or recovered in spawning areas. The number of chum in the tagging sample appeared to be representative of run strength in both 1982 and 1983. Tag returns were received from commercial, native subsistence, and domestic fishermen.

The conditions or requirements of a mark-recapture study most difficult to assess in this study were:

A. the natural mortality of tagged fish

B. the vulnerability of tagged fish to recapture

C. the reporting of all recaptured tags

Conditions A and B involve the behavioural and physiological effects of tagging (Appendix 9). Little is known about these effects because they are difficult to study under field conditions. Apart from the radio-tagging portion of the study, no attempt was made to study the effects of tagging on Yukon River chum salmon. It is difficult to compare radio-tagging with spaghetti tagging in terms of conditions A and B because they involve different techniques; however, behavioural responses resulting from radio-tagging may be similar to behavioural responses resulting from spaghetti-tagging (Appendix 9). As noted previously, Yukon River chum migrate over approximately 1900 km in freshwater before reaching the tagging site(s) and must travel an additional 300-800 km upriver to reach spawning destinations. The physiological demand of this non-feeding migration must be a critical limitation of spawning success.

Marked fish could potentially suffer greater mortality than unmarked fish because of disorientation and stress which could result from confinement, handling, and tagging. For similar reasons, marked fish may not be randomly distributed. It is important to note that tagging procedures have been known to cause erratic movements for some days or even weeks (Ricker, 1975). If a number of tagged fish are unavailable for recapture, the population will be overestimated, and, conversely, if the tagged fish are recaptured at a higher rate than untagged fish, the population will be underestimated.

As regards condition C, tag returns may have gone unreported for reasons that include a possible indifference of some fishermen to the tagging program, and perhaps fear on the part of some fishermen that a large number of tag returns could result in fishing restrictions. It may be possible to overcome indifference by providing more attractive incentives for tag return, and to allay fishing restriction fears by assuring anonimity of the fishermen returning the tags.

The use of an improved tag type and reduced confinement and handling would result in a more efficient tagging procedure, subjecting the salmon to less physiological stress. The following recommendations should be considered for future tag-recovery programs.

1. Confinement in the holding pens should be restricted to a minimum holding period of approximately two hours. This would require additional field personnel and 24-hour tagging.

2. Tag application should occur while the fish is in the water. Tagging could occur in a more specialized holding pen designed solely for this purpose.

3. The development and use of another tag type should be considered.

4.2 Chum Habitat Selection

The results of this study indicate that chum spawning sites in the upper Yukon River Basin are frequently, although not invariably, associated with upwelling groundwater. Other northern fall chum stocks in Alaska (Kogl, 1965) (Barton, 1982), in the Fishing Branch River in the northern Yukon (Elson, 1976), and in the Amur River in the U.S.S.R. (Kogl, 1965) use similar spawning habitat. All undertake extensive freshwater migrations to spawn in spring-fed areas that may remain ice-free throughout the winter months. The association between spawning sites and upwelling groundwater is not unique to northern chum populations, but groundwater areas may be more important to northern chum populations because they are subjected to the direct and indirect effects of very low winter temperatures. The selection of groundwater areas with high intragravel temperatures appears to be an adaptation that enhances survival during the winter-long incubation period. Salmonids in general are most vulnerable during this portion of their life cycle, and the high intragravel groundwater temperatures probably reduce the possibility of redds (salmon nests) freezing despite shallow water depths, low water flow, and the below-freezing temperatures of sub-Arctic winters.

4.3 Canadian Fall Chum Production within Yukon River Drainage

Three of the five sub-basins within the study area, the White, mainstem Yukon, and Teslin sub-basins, are important fall chum producers. Chum production in the Stewart and Pelly sub-basins appears to be minimal, although further research is needed to substantiate this. The Porcupine sub-basin in the northern Yukon is another important fall chum producer (Elson, 1973, 1976; Alaska Department of Fish and Game, 1982), although it was excluded from the study area.

In the following discussion, available population and escapement information is reviewed and used to determine preliminary estimates of the overall importance of Canadian fall chum production areas to the production from the entire Yukon River drainage. It is important to develop preliminary production estimates because they inevitably will be required in developing a salmon interception agreement and effective management strategies for the Canadian fall chum resource. Because of its obvious importance, the Porcupine sub-basin is included in this discussion.

Prior to this study, information on the chum resource within Canada was primarily derived from fishwheel tagging studies conducted in the Dawson area (Table 1), from the operation of a weir on the Fishing Branch River between 1971 and 1975 (Elson, 1973, 1976), and from an intensive study of the mainstem Yukon in the Minto area (Walker, 1976). The tagging studies indicate that the annual escapement to the upper Yukon River drainage was in the order of 25,000-30,000 chum, which was probably a conservative estimate because the tagging studies were conducted during years with average to below average chum returns. The population estimates determined in this study were significantly higher and ranged from 47,049 chum in 1982 to 118,365 chum in 1983. The high 1983 return suggests that upper Yukon chum stocks follow a cycle year pattern similar to the one observed in the Fishing Branch River, where peak cycle year returns occurred in 1971 and 1975, with escapements totalled 250,000-300,000 and 353,282 chum, respectively (Appendix 10). The escapements observed during the most recent cycle year returns to this system were 44,000 in 1979 and 10,000 in 1983, determined with aerial survey techniques; the total calculated escapements were 75,000 in 1979 and 35,000 in 1983.

An estimate of the total fall chum production within Canadian portions of the Yukon River basin was determined from catch and escapement information (Appendix 10). As mentioned previously, the Canadian production of fall chum occurs primarily in the Fishing Branch River and in three sub-basins within the upper Yukon drainage. The average escapement to the Fishing Branch River was approximately 65,000 chum between 1971 and 1983. A conservative estimate of the annual escapement to the upper Yukon drainage is 29,000 chum (Appendix 10). The annual escapement to Canadian portions of the Yukon drainage is therefore in the order of magnitude of 94,000 chum.

The two principal Alaskan producers of fall chum are the Tanana and Sheenjek Rivers. The average escapements to those systems were as follows:

Tanana River System	61,000	(1972-1983)
Sheenjek River System	33,000	(1973-1982)

A small fall chum return to the Black and Salmon - Trout Rivers in Alaska averaged approximately 1,200 between 1974 and 1977. The total annual fall chum escapement to Alaskan portions of the Yukon River drainage is in the order of 95,000 chum.

The gross escapement information presented above indicates that the fall chum production in Canada approaches 50% of the total Yukon River drainage production, although actual production probably varies annually. An overall Canadian production estimate of 40.7% was determined from the information presented in Appendix 10, and the highest estimates of Canadian production ranged from 30% to 69% (55% average) between 1971 and 1975 during the period when the Fishing Branch River weir was in operation. A low estimate of 3,090 for the total Canadian contribution between 1976 and 1982, could be attributable to the survey techniques used during Fishing Branch River surveys and the lack of population estimates determined for upper Yukon stocks between 1976 and 1981. The reliability of information from aerial surveys of the Fishing Branch River is questionable, but they do provide an indication of relative run strength (Elson, 1973).

The combined Canadian and Alaskan fall chum commercial catches averaged 272,020 between 1971 and 1983. Based on the assumption that commercial exploitation levels range from 40 to 60%, the average annual chum return to the Yukon River in the 1971-1983 period was estimated to range from 453,351 to 680,050 with an upper limit of approximately 900,000 chum (Appendix 10). An average fall chum population estimate of 627,000, derived from Alaskan tagging studies conducted between 1975 and 1979 (Table 2), corresponds with the run magnitude of 680,050 as determined at an exploitation rate of 40%.

The production of fall chum within Canadian portions of the Yukon River Basin represents a significant percentage of the overall Yukon drainage production. These preliminary production estimates should be substantiated with continued population and escapement estimates.

4.4 Recommendations

The recommendations of this report are as follows:

1. Joint management and research should be initiated with the Alaska Department of Fish and Game. A biological committee representing both governments would monitor the status of the resource and provide the framework required for a future management agreement.

2. An annual chum tag-recovery program should be conducted above the Yukon/Alaska border. This program will provide a consistent data base of annual population estimates, escapement estimates, and exploitation rates within Canadian waters.

3. The management of the Canadian chum resource should involve weekly fishing periods that are varied to reflect run strength. Emphasis should be placed on maintaining adequate escapement stocks to ensure that overexploitation of the resource does not occur.

4. A number of chum spawning areas should be selected as index areas and annually monitored. These areas should be located in at least two of the principal spawning tributaries such as the Kluane River and the mainstem Yukon River.

5. Detailed studies of chum spawning habitat should be initiated. Additional surveys of ice-free areas would be useful in locating new spawning sites and in predicting changes in spawning habitat.

6. A life history study of juvenile chum should be initiated. Investigations should involve overwintering requirements, survival rates during the egg to fry period, timing of out-migration, and possible feeding behaviour. A pre-emergent fry index may be useful in predicting cycle year returns.

7. The contributions of the Fishing Branch River to the overall Canadian chum production should be updated through the operation of a counting weir.

8. An annual report on the current status of the chum resource should be available to the general public, and to all commercial, domestic, and subsistence fishermen in the Yukon Territory.

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Appendix 1 Comparative Yukon River drainage fall chum aerial escapement estimates, 1973-1982 (A.D.F.& G., 1982).

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
TANANA RIVER DRAINAGE										
Bear Paw River	1,530	2,996	1,657	--	--	--	--	--	--	--
Toklat River drainage										
Upper Toklat River[b]	6,957	34,310	42,418[d]	35,190	21,800[d]	35,000	96,550[d]	23,054	13,907	3,309[e]
Lower Toklat River	--	--	35,867[d]	2,000[c,d]	--	--	64,540	2,140	--	--
Subtotal Toklat R. drainage	6,957[d]	34,310[d]	78,285[d]	37,190	21,800[d]	35,000[d]	161,090	25,194	13,907[d]	3,309[d]
Upper Tanana River drainage										
Benchmark #735 Slough	127[d]	1,450	--	336	1,270	1,705[d]	2,714	1,900[e]	168[d]	--
Delta River	7,971	4,010	3,089[e]	5,498	17,925	10,051	8,125	4,637	22,375[e]	3,433[e]
Upper Tanana River[f]	5,635	4,567	--	4,979	3,797	5,700	20,820	3,444	7,063	--
Bluff Cabin Slough	3,450	4,840	5,000[c,e]	3,197	6,491	5,340	6,875	3,190	6,120	1,156[e]
Delta Clearwater Slough (Onemile Slough)	1,720	1,235	745[c]	1,552	1,900	475	3,850[d]	885[d]	632	--
Subtotal Upper Tanana R. drainage	18,903	16,102	8,834[d]	15,562	31,383	23,271	42,384	14,056	36,358	4,589[d]
SUBTOTAL TANANA R. DRAINAGE	27,390	53,408	88,776	52,752	53,183	58,271	203,474	39,250	50,265	7,898
PORCUPINE RIVER DRAINAGE										
Sheenjek River	1,175[d]	40,507	78,060	11,866	20,506	14,610[d]	41,140	13,027	69,043[g]	29,093[g]
Black River drainage			50							
Salmon Fork River	--	444	1,517	0[d]	--	--	--	--	--	--
Kevenjik Creek	--	1,625	582	7[d]	--	--	--	--	--	--
Fishhole Creek	--	--	--	--	200[d]	--	--	31[d]	--	--
Subtotal Black R. drainage	--	2,069	2,149	7	200			31	--	--
Salmon-Trout River	--	6	350	20	--	--	--	--	--	--
Fishing Branch River (YT)	15,987[h]	32,525[h]	353,282[h]	13,450	32,500	15,000	44,080	20,319[d]	10,549[d]	5,846
SUBTOTAL PORCUPINE R. DRAINAGE	17,162	75,107	433,841	25,343	53,206	29,610	85,220	33,377	79,592	34,939

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[a] All surveys rated fair-good unless rated otherwise. Only peak estimates listed.

[b] Includes following areas: Toklat River in vicinity of roadhouse, Shushana River, and Geiger Creek.

[c] Combined aerial and ground survey estimates.

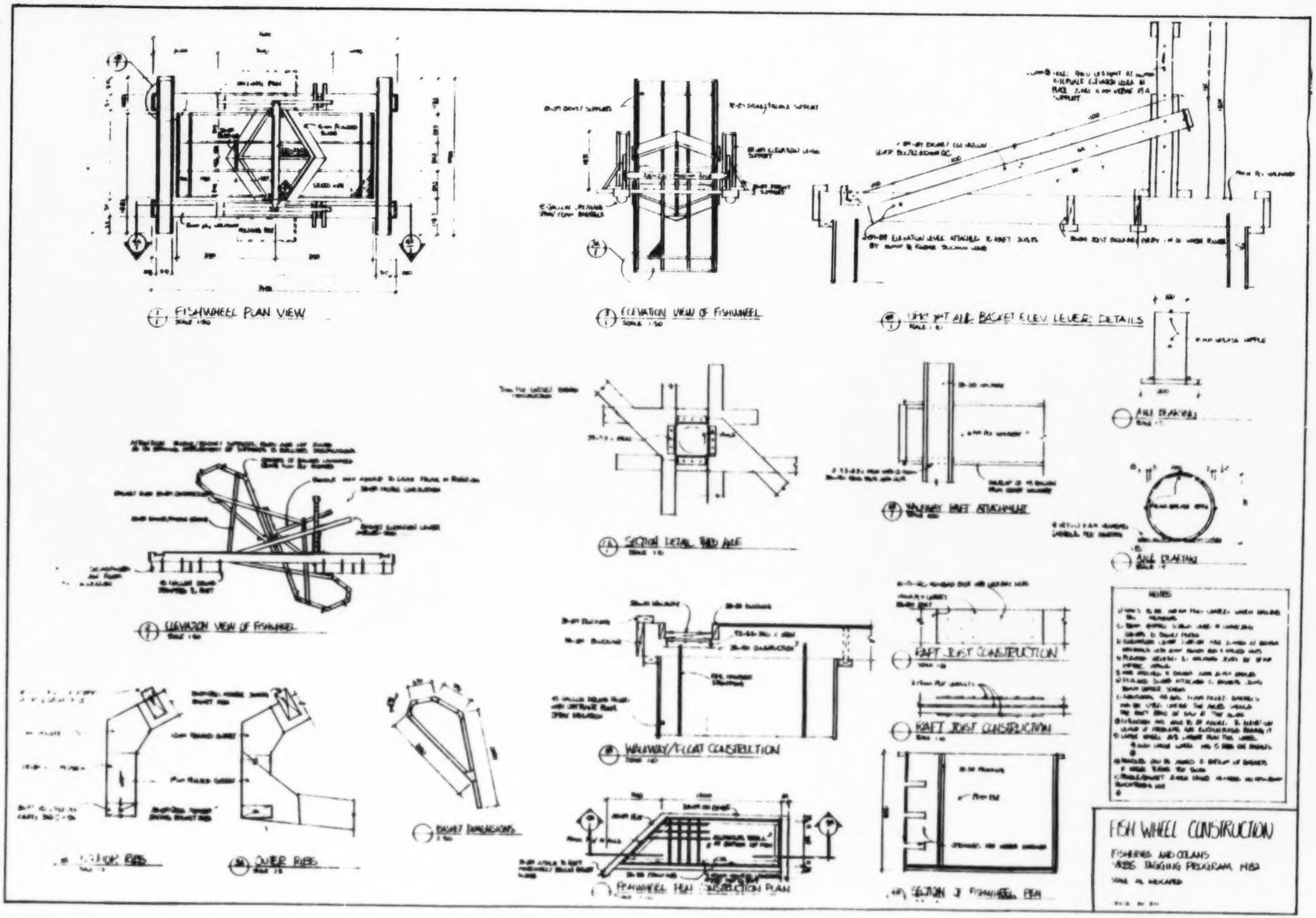
[d] Poor or incomplete survey; very minimal and/or rough estimate.

[e] Foot survey.

[f] Richardson Highway bridge to Blue Creek.

[g] Sonar count.

[h] Weir count.


FISHWHEEL PLAN VIEW
ELEVATION VIEW OF FISHWHEEL
BASKET ELEV LEVER DETAILS
AXLE BEARING
WALKWAY RAFT ATTACHMENT
SECTION DETAIL THRU AXLE
ELEVATION VIEW OF FISHWHEEL
AXLE BEARING
NOTES
RAFT JOIST CONSTRUCTION
RAFT JOIST CONSTRUCTION
WALKWAY/FLOAT CONSTRUCTION
BASKET DIMENSIONS
OUTER RIBS
FISHWHEEL RAFT CONSTRUCTION PLAN
SECTION THRU FISHWHEEL RAFT
FISH WHEEL CONSTRUCTION
FISHERIES AND OCEANS
TAGGING PROGRAM 1982

Appendix 2 Fishwheel design

Appendix 3 Spaghetti tag recoveries on the Donjek and Kluane Rivers 1983

TAG NUMBER	RECOVERY LOCATIONS	DATE TAGGED	TAGGING LOCATION	DATE RECOVERED
00066	KM 334	21/08/82	L.W.	20/10/83
00100	331	23/08/83	L.W.	20/10/83
00207	328	28/08/83	U.W.	19/10/83
00222	KM 461 or 195 Donjek River	29/08/83	L.W	18/09/83
00274	328	30/08/83	U.W.	19/10/83
00391	333	01/09/83	L.W.	20/10/83
00425	328	01/09/83	S.R.W.	19/10/83
00592	328	03/09/83	U.W.	19/10/83
00595	328	03/09/83	U.W.	19/10/83
00610	328	03/09/83	S.R.W.	19/10/83
00611	334	03/09/83	S.R.W.	20/10/83
00665	328	04/09/83	S.R.W.	19/10/83
00668	334	04/09/83	S.R.W.	20/10/83
00683	325	04/09/83	L.W.	18/10/83
00703	328	04/09/83	S.R.W.	19/10/83
00704	328	04/09/83	S.R.W.	19/10/83
00803	328	05/09/83	L.W.	19/10/83
00892	334	06/09/83	U.W.	20/10/83
00917	328	06/09/83	L.W.	19/10/83
00956	328	06/09/83	S.R.W.	19/10/83
00976	334	07/09/83	U.W.	20/10/83
18819	328	07/09/83	L.W.	19/10/83
18947	325	09/09/83	S.R.W.	18/10/83
01124	328	12/09/83	L.W.	19/10/83
15815	328	12/09/83	U.W.	19/10/83
01039	331	13/09/83	U.W.	20/10/83
01051	328	13/09/83	S.R.W.	19/10/83
01053	328	13/09/83	S.R.W.	19/10/83
01334	328	13/09/83	L.W.	19/10/83
01405	325	13/09/83	L.W.	18/10/83
01417	331	13/09/83	L.W.	20/10/83
01174	328	14/09/83	U.W.	12/11/83
01193	328	14/09/83	S.R.W	19/10/83
01209	325	14/09/83	L.W.	18/10/83
01229	328	14/09/83	S.R.W.	19/10/83
01230	328	14/09/83	S.R.W.	19/10/83
01259	333	14/09/83	U.W.	20/10/83
01317	325	14/09/83	L.W.	18/10/83
01151	328	15/09/83	U.W.	19/10/83
01446	328	21/09/83	L.W.	12/11/83

* L.W. - Lower Fishwheel km 12
U.W. - Upper Fishwheel km 15
S.R.W. - Sheeprock Fishwheel km 18

Appendix 4

Spaghetti tag recoveries mainstem Yukon 1983

Tag Number	Recovery Locations	Date Tagged	Tagging* Location	Date Recovered
00454	429	01/09/83	S.R.W	12/10/83
00632	416	03/09/83	U.W.	24/10/83
00802	441	05/09/83	L.W.	12/10/83
01289	369	14/09/83	L.W.	23/10/83
01382	429	13/09/83	S.R.W	24/10/83
01450	416	21/09/83	L.W.	24/10/83
01488	408	20/09/83	S.R.W.	22/10/83
01629	415	17/09/83	S.R.W.	12/10/83
02192	429	22/09/83	S.R.W.	24/10/83
02263	439	24/09/83	S.R.W.	12/10/83

*L.W. - Lower Fishwheel km 12

U.W. - Upper Fishwheel km. 15

S.R.W. - Sheep Rock Fishwheel km 18

Appendix 5

Chum radio tagging schedule 1982

DATE		NO.OF TAGS APPLIED
Aug.	28	3
Aug.	30	3
Aug.	31	2
Sept.	1	3
	2	4
	3	3
	4	3
	5	4
	6	4
	7	2
	8	4
	10	4
	11	1
	12	2
	13	6
	14	4
	16	5
	17	2
	18	4
	19	3
	20	2
	21	3
	22	1
	23	2
	24	5
	25	6
	26	5
	27	2
	29	3
	30	3
Oct.	1	2
	2	3
	3	5
	4	2
	5	1
	6	2
	7	1

114 Tags Applied

APPENDIX 6

Transmitter recoveries in commercial, subsistences and domestic fisheries

FISH #	FREQUENCY	DATE TAGGED	TAGGING LOCATION (KM)	DATE RECAPTURED	RECAPTURE LOCATION	KM	TOTAL DISTANCE TRAVELLED (KM)	COMMENTS *
2	150-665	28/8/82	0	3/9/82	Swede Ck.	148	148	S Initially captured by gillnet-held 14 hours.
3	150-885	29/8/82	5	4/9/82	Dawson	140	135	C Initially captured by gillnet.
5	150-946	30/8/82	5	8/9/82	Sister Is.	135	130	C Recaptured in Weldon Farr's fishwheel.
6	150-966	30/8/82	5	1/9/82	Cliff Ck.	44	39	
9	151-065	1/9/82	5	5/9/82	Fifteen Mile R.	101	96	C Tag seated well in gut
10	150-087	1/9/82	5	3/9/82	40 Mile R.	58	53	C Recovered in net of mouth of 40 mile.
12	151-305	2/9/82	5	5/9/82	Sister Is.	135	130	C Recaptured in Weldon Farr's fishwheel tag seated well in gut.
13	151-523	2/9/82	5	4/9/82	Cliff Ck.	42	37	C
15	150-587	2/9/82	5	5/9/82	Fishwhell #2	5	37	C Recovered in shallow water, gut perforated, liver and spleen damaged by whip antennae - assumed fish was net fouled.
18	150-665	3/9/82	5	5/9/82	Sheep Rock	16	11	C
27	151-523	6/9/82	5	9/9/82	Sister Is.	135	130	C
28	151-006	6/9/82	5	8/9/82	Fifteen Mile R.	101	96	C Recovered in Han Fishplant
30	151-987	7/9/82	5	9/9/82	Fifteen Mile R.	101	96	C Recovered in Han Fishplant

...../2

APPENDIX 7

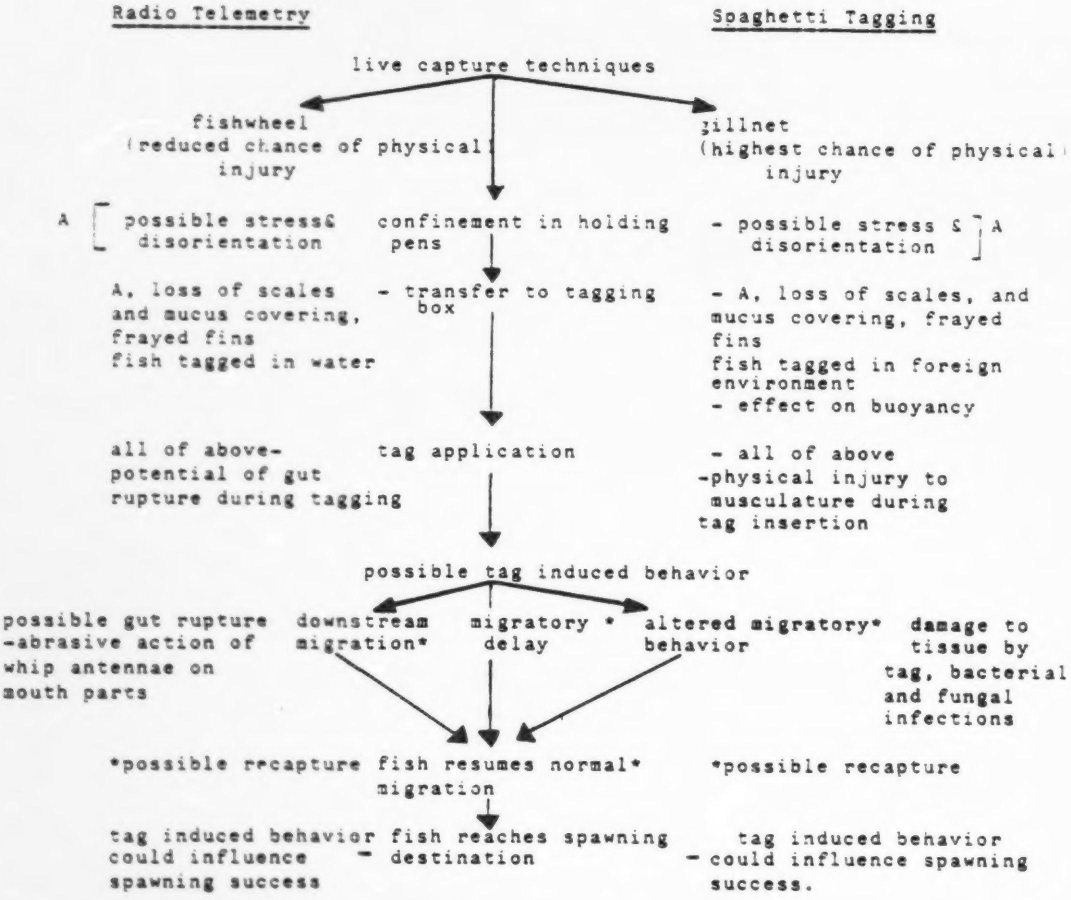
Radio transmitter recoveries

FISH #	FREQUENCY	DATE TAGGED	TAGGING LOCATION (KM)	DATE RECAPTURED	RECAPTURED LOCATION	KM	TOTAL DISTANCE TRAVELLED (KM)	COMMENTS
1	150-828	28/8/82	0	9/10/82	White R	342	342	Frequency drift 826 to 828, predator kill-tag buried in thicket.
4	150-907	30/8/82	5	8/10/82	Donlek R	476	471	Recovered on sandbar-no carcass-toothmarks on tag-predator kill.
7	151-025	31/8/82	5	29/9/82	Klondike R	149	144	Predator kill-tag on bank beside spaghetti tag-grizzly tracks.
19	150-707	4/9/82	5	22/10/82	Ingersoll Is.	416	411	Predator kill-recovered on ground in spawning area-heavy grizzly predation.
21	150-747	4/9/82	5	22/9/82	Minto	432	427	Recovered on spawning ground fresh bear kill-spawning just underway.
37	151-146	10/9/82	5	23/9/82	Kluane R	592	587	Predator kill-recovered on spawning grounds.
48	151-245	13/9/82	5	20/10/82	Below Fort Selkirk	370	365-427	Predator kill - fish had been initially observed on grounds further upriver.
58	151-566	17/9/82	5	12/10/82	Bio Is.	5	0	Regurgitated tag.
69	151-045	21/9/82	5	11/10/82	Swede Ck.	159	154	Recovered on sandbar.
112	151-387	6/10/82	135	11/10/82	Swede Ck. Area	148	13	Regurgitated tag.

Appendix 8 Differences in radio telemetry and spaghetti tagging techniques

Radio Tagging	Spaghetti Tagging
Objectives	
- generally directed towards qualitative information	quantitative information
migratory behavior	population estimates
spawning locations	exploitation rates
migration rates	migration rates
Methods	
- internal tag (implant)	external tag
- located near centre of gravity	- loose fitting
- small relative to prey species	- light, does not impede mobility
- tag appl. requires 10 sec.-1 min.	- tag applic. requires 25 sec.-1 min.
- fish tagged while in water	- fish tagged in foreign environment
Results	
- continuous information after after fish is released through aerial or ground tracking.	- no information is generated until fish is recaptured or tag is retrieved from spawning area.
Limitations	
- limitations on signal range due to depth of fish in water, conductivity of water, orientation of receiver etc.	- under field conditions its not possible to directly assess the effect of handling, tagging on the behavior of the fish.
-possible tag regurgitation	- possible tag loss
- possibility that the transmitter may influence behavior.	- possible violations of the conditions in a mark-recapture program.

Appendix 9 Potential behavioral and physiological responses to tagging techniques


Radio Telemetry
Spaghetti Tagging
live capture techniques
fishwheel (reduced chance of physical injury)
gillnet (highest chance of physical injury)
A possible stress& disorientation
confinement in holding pens
- possible stress & disorientation A
A, loss of scales and mucus covering, frayed fins
fish tagged in water
- transfer to tagging box
- A, loss of scales, and mucus covering, frayed fins
fish tagged in foreign environment
- effect on buoyancy
all of above- potential of gut rupture during tagging
tag application
- all of above
-physical injury to musculature during tag insertion
possible tag induced behavior
possible gut rupture
-abrasive action of whip antennae on mouth parts
downstream migration*
migratory * delay
altered migratory* behavior
damage to tissue by tag, bacterial and fungal infections
*possible recapture
fish resumes normal* migration
*possible recapture
tag induced behavior could influence spawning success
- fish reaches spawning destination -
tag induced behavior could influence spawning success.

Appendix 10

Fall chum catch and escapement - Yukon River

YEAR	COMBINED CANADIAN ALASKAN COMMERCIAL CATCH	RIVER POP. AT 40% EXPLOIT RATE	RIVER POP. AT 60% EXPLOIT RATE	ESCAPEMENT					TOTAL OBSERVED ESCAPEMENT	CANADIAN CONTRIBUTION TO TOTAL ESCAPEMENT (PERCENT)
				FISHING BRANCH RIVER	UPPER YUKON	TANANA R. DRAINAGE	SHEENJEK RIVER	BLACK AND SALMON - TROUT RIVERS		
1971	191,355	478,387	318,925	250-300,000	25-30,000	-	-	-	275-325,000	100
1972	154,708	386,770	257,847	35,125	25-30,000	23,295	-	-	83,420	72
1973	234,896	587,240	391,493	15,987	29,700	27,390	1,175	-	76,321	60
1974	279,884	699,710	466,473	32,525	21,400	53,408	40,507	2,069	149,909	36
1975	267,656	669,140	446,093	353,282	25-30,000	88,776	78,060	2,499	547,617	69
1976	164,282	410,705	273,803	13,450	25-30,000	52,752	11,866	27	103,095	37
1977	252,729	631,822	421,215	32,500	25-30,000	53,183	20,506	200	131,389	44
1978	247,093	617,732	411,822	15,000	3,700*	58,271	14,610	-	91,581	20
1979	372,564	931,410	620,940	44,080	25-30,000	203,474	41,140	-	313,694	22
1980	307,123	767,807	511,872	20,319*	25-30,000	39,250	13,027	0	97,267	46
1981	501,319	1,253,297	835,331	10,549*	25-30,000	50,265	69,043	-	154,857	23
1982	236,347	590,867	393,911	5,846	32,432	7,898	29,093	-	75,269	51
1983	329,741***	824,352	549,568	10-30,000*	70,000	75,221****	45,733	-	200,954	40
Average 1971-1983						Average 1972-82	Average 1973-83	Average 1974-77		
	272,284	680,710	453,806	64,512	29,461**	61,099	33,160	1,199	178,979	48

Upper Yukon - 25-30,000 figures are based on estimated minimum escapement
* Poor or incomplete survey; very minimal and/or rough estimate
** Excludes 1978
*** Preliminary Figure
**** 1983 count not available - 4 year average used
All information from Alaska Department of Fish and Game and Department of Fishery Files